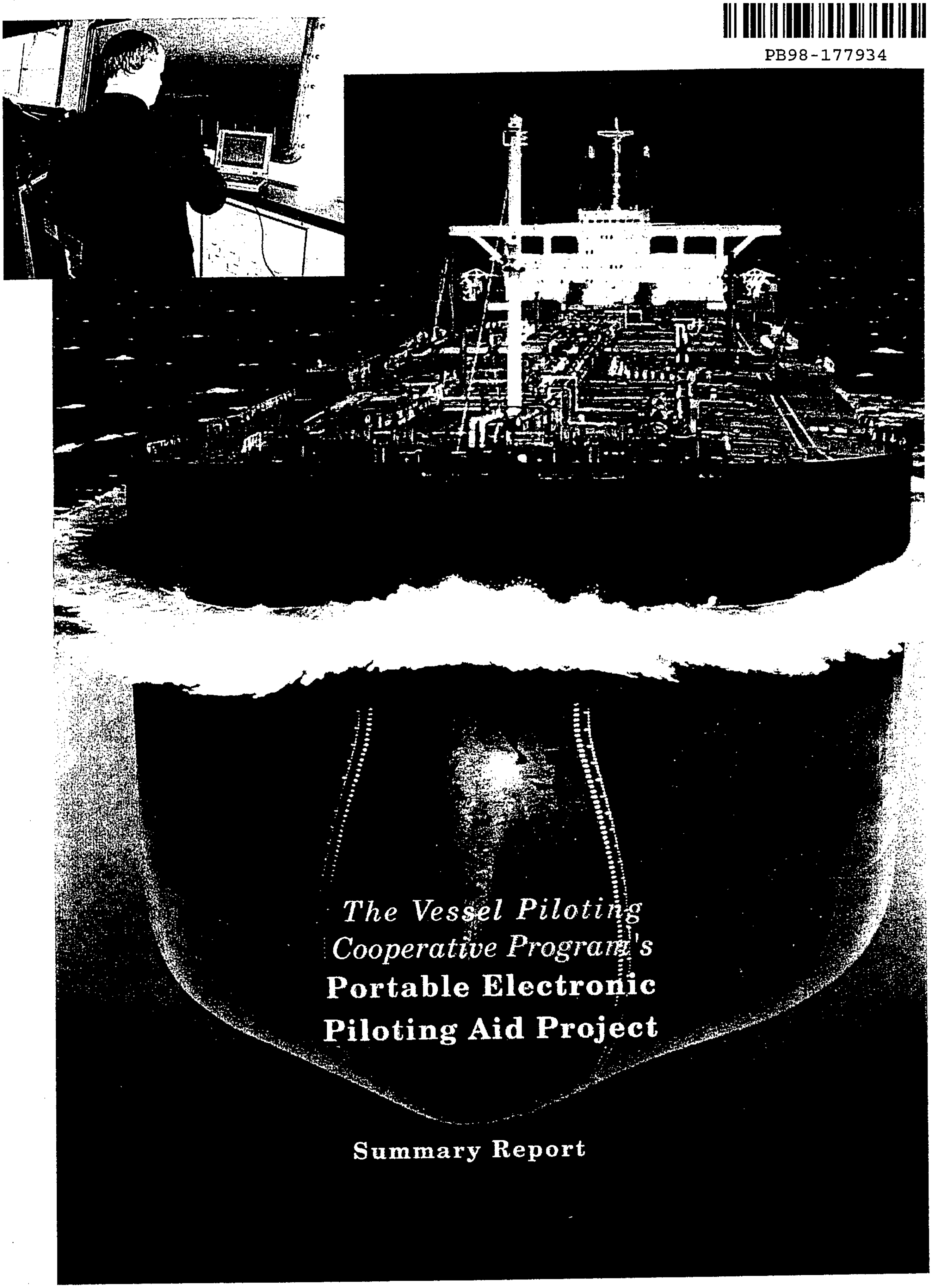
PB98-177934



# *The Vessel Piloting Cooperative Program's* Portable Electronic Piloting Aid Project

## Summary Report



U.S. Department of Transportation
**Maritime Administration**

# REPORT DOCUMENTATION PAGE

*Form Approved*
*OMB No. 0704-0188*

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

**1. AGENCY USE ONLY** *(Leave blank)*

**2. REPORT DATE** APRIL 1998

**3. REPORT TYPE AND DATES COVERED** FINAL

**4. TITLE AND SUBTITLE**
*Vessel Piloting Cooperative Program's*
Portable Electronic Piloting Aid Project
Summary Report

**5. FUNDING NUMBERS**
DTMA91-95-H-00039

**6. AUTHOR(S)** Editor & Principal Author: Vincent Kirby;
Contributors: Wayne Bailey & Joseph Bradley, Carl Bowler, Joseph Frees, Frederick Ganjon, Kermit Kapp, James Maida, Andrew McGovern, Richard Morrison, Chuck Parker, William Parrish, David Petrazewski, Larry Simpson, Donald Sytsma, Brian Tahaney, Daniel Waldeck, Joseph Warfield, Colin Weeks, Donald Willecke

**7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)**

Office of Labor, Training & Safety
U.S. Maritime Administration
400 7th Street SW
Washington, DC 20590

Volpe National Transportation Systems Center
Kendall Square
Cambridge, MA 02142

**8. PERFORMING ORGANIZATION REPORT NUMBER**

**9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)**

Office of Labor, Training & Safety
U.S. Maritime Administration
400 7th Street SW
Washington, DC 20590

Volpe National Transportation Systems Center
Kendall Square
Cambridge, MA 02142

**10. SPONSORING / MONITORING AGENCY REPORT NUMBER**
MA-RD-250-98000

**11. SUPPLEMENTARY NOTES**



**12a. DISTRIBUTION / AVAILABILITY STATEMENT**



**12b. DISTRIBUTION CODE**

**13. ABSTRACT** *(Maximum 200 words)*

This report describes the activity and findings of the Vessel Piloting Cooperative's Evaluation Project of Portable Electronic Piloting Aid (PEPA) systems for ship pilots.

Technological developments in the field of navigational technology, including electronic charting and Differential Global Positioning Systems (DGPS), have made possible the manufacture of highly accurate, carry-aboard navigational computers designed specifically for use by ship pilots. Over a two year period, the Piloting Cooperative's forum, the APA Navigation & Technology Committee, with the assistance of the Volpe National Transportation Systems Center and the U.S. Maritime Administration, conducted a multi-step project designed to investigate this technology and its utility for the practice of piloting. The study team: solicited participation from all known and interested PEPA manufacturers; encouraged the development of prototype units for a set of test ports throughout the country; monitored the implementation of the most promising systems in the test ports; and conducted trials and evaluation of the equipment through survey and personal assessment by working pilots. From the evaluation data gathered, the study team formulated a set of conclusions to enhance the application and improvement of PEPA technology. From analysis of the overall project and issues not fully addressed in the Evaluation data, the study team formulated a set of additional conclusions to further enhance the application and improvement of PEPA technology.

**14. SUBJECT TERMS** Portable Electronic Piloting Aid (PEPA); Differential Global Positioning System (DGPS); Electronic Chart Display & Information System (ECDIS); Vessel Traffic Service (VTS); Vessel Traffic Information Service (VTIS); Automated Information System (AIS).

**15. NUMBER OF PAGES** 153

**16. PRICE CODE**

**17. SECURITY CLASSIFICATION OF REPORT**

**18. SECURITY CLASSIFICATION OF THIS PAGE**

**19. SECURITY CLASSIFICATION OF ABSTRACT**

**20. LIMITATION OF ABSTRACT**

# *The Vessel Piloting Cooperative Program's* Portable Electronic Piloting Aid Project

# Summary Report

# EXECUTIVE SUMMARY

## PROGRAM BACKGROUND

In March of 1995, a cooperative agreement was signed between the American Pilots' Association (APA) and the U.S. Maritime Administration (MARAD). The agreement established a profession-led cooperative Research and Development program. The mission of the Piloting Cooperative was identified as defining and conducting R&D projects determined to enhance safety and efficiency in U.S. piloting operations. The focus of the Cooperative was established as addressing pilot-identified and prioritized research projects which U.S. pilots consider to be of the greatest potential benefit to the profession. The APA's Navigation and Technology Committee became the coordinating forum for the Cooperative, providing the necessary expertise in refining project ideas and guiding project development. A modest level of direct funding was provided by MARAD for project efforts, including coordinating and technical assistance provided by the Volpe National Transportation Systems Center (VNTSC).

From the beginning of the Cooperative's consideration of various research projects, it was clear there was strong interest and support for an investigation of "carry-aboard" navigational computers. A number of developments in navigational technology had combined to make possible a first generation of portable electronic piloting aid systems designed specifically for use by marine pilots. Several of these portable electronic piloting aid (PEPA) units were entering the marketplace, and a number of manufacturers were considering the design of prototype units for this market. Manufacturers claimed a wide range of capabilities for their systems. Some systems required the utilization of emerging technology not yet adapted for commercial marine application. It was obvious to the Cooperative Team that both the utility and reliability of this technology required evaluation, as well as its impact on the practice of piloting itself. The Cooperative designated the evaluation of portable electronic piloting systems as its first project.

## PORTABLE ELECTRONIC PILOTING AID PROJECT

The objectives of the Portable Electronic Piloting Aid Project were:

- To facilitate research and development in the area of portable electronic piloting systems through assessment of the state-of-the-art and evaluation of various portable electronic navigation aid systems for piloting purposes.
- To encourage exchange of information and experience with PEPA technology among U.S. piloting associations, current and potential manufacturers of PEPA equipment, and the maritime community at large.
- To assess the utility of the technology as it currently exists and to gain insight into the impact of this technology on the practice of piloting.

The Cooperative Team accomplished the following tasks:

1) Identified pilot associations and pilotage waterways to be involved with the evaluation of portable electronic piloting aids.
2) Identified available technology sources and services for portable Differential GPS navigation units and arranged for the representative pilot associations to acquire

units for on-the-job trial, assessment, and evaluation by the piloting associations and their members.

3) Identified elements of units to be evaluated and structured these elements into a PEPA Evaluation Form.

4) Performed evaluations of the equipment and its utility for pilotage functions under different conditions through survey and personal assessment. Data gathered on the physical characteristics of the units, data sources available, accuracy of the data, presentation formats, methodologies for using the data, ease of use of the unit, value in the aid of piloting, communications issues, general utility, research/design issues, future needs/developments/ recommended improvements, etc.

5) Collected evaluation survey data and assessed results, developing a report of the evaluation efforts.

6) Drafted a comprehensive report presenting the pilot research program and evaluation results, describing pilot experiences with the equipment, and noting future needs and recommended improvements for navigation and communication technologies for improving safety and efficiency of piloting operations.

## MANUFACTURER PARTICIPATION

In July 1995 and the months thereafter, 15 manufacturers were notified of the Portable Electronic Piloting Aid Project and encouraged to participate. They included all known manufacturers in the United States as well as three foreign manufacturers. Some of these manufacturers already had working units on the water or prototype units ready for trial; other manufacturers had systems in the design stage. Manufacturer expertise and interaction with the pilot associations was considered essential in enhancing the education of the pilot population about the technology. Throughout the duration of the project, communication between pilot associations and manufacturers was encouraged and supported by the Cooperative Team.

At the time the project began, many system performance claims were made by a number of these manufacturers to pilot associations and the pilot population at large. Some of these claims were fulfilled by the manufacturers - others were not. Relationships were formed between specific pilot associations and specific manufacturers. These relationships fulfilled the Cooperative's laissez faire goal of empowering individual associations to select and evaluate whatever systems they deemed the best for their specific needs and waterways.

During the course of this project, there was a marked consolidation of manufacturers who remained with the project. Some manufacturers experienced financial trouble unrelated to their involvement in the project and went out of business; others found disfavor among the pilot population for making promises they could not keep and/or for not supporting the associations in the design and evaluation period; other manufacturers offered systems which were simply too expensive; still others withdrew from the market for unidentified reasons. What resulted at the end of the project were a few manufacturers whose equipment was considered worthy of evaluation by U.S. pilot associations who offered service and equipment which was both well supported and operational. Participation in the project on the part of these manufacturers was extensive; many made contributions included in this Summary Report.

## PEPA SYSTEMS

The PEPA units evaluated as part of this project were all similar in system design. They all utilize an off the shelf notebook computer linked to a GPS/DGPS receiver and portable antenna, and use U.S. Coast Guard or commercially-broadcast Differential GPS signals to display own-ship position on a very accurate vector chart customized for the specific pilot association's body of water. They provide primarily own-ship navigational information and were all manufactured in the last few years.

Among the developments of PEPA technology currently being considered, evaluated, and/or installed by select U.S. pilot associations is the use of a wireless digital communication link to tie together individual pilot carry-aboard units. In such a system, the information provided by individual units is transmitted at frequent intervals (as often as once per second) to the other units in the system, providing each pilot with voiceless information on each ship in the system as well as his own. There are a number of different communications technologies being considered and/or evaluated by U.S. pilot associations to install such systems - each with their own advantages and disadvantages - and a number of issues surrounding the implementation of these systems. Opinions vary widely among pilots regarding the utility, application, reliability, and cost effectiveness of these systems. More than in any other area of PEPA development, this area of multi-ship systems and the communication links they employ is very much in its infancy. Complicating the picture are a number of factors, including the fast pace of the telecommunications industry's development of wireless digital communications technology and the corresponding application innovations likely to occur in the future.

## EVALUATION BACKGROUND

The main focus of the Piloting Cooperative's Portable Electronic Piloting Aid Project involved an evaluation of established and prototype commercially-manufactured portable units by working pilots in ports throughout the United States. Such a qualitative evaluation by the end users of the technology in actual working practice was determined by the members of the Piloting Cooperative as the best way to assess the utility of this new technology and gain some insight into its impact on the practice of piloting.

In order to insure an equitable national geographic representation for the evaluation, the country was broken down into five regions: North Atlantic, South Atlantic, Gulf Coast, Pacific Coast, and Great Lakes. From these regions specific ports for portable electronic piloting aid technology evaluation were identified in April of 1996. The pilot associations were selected to participate within each region on the basis of: type of waterway and geography of the port, known unique piloting challenges/conditions where the application of the technology was anticipated to yield valuable data, experience of the pilot association with the technology, interest of the pilot association in the technology, and willingness of the association to participate in the evaluation. The ports selected involved a full range of piloting operations and navigational challenges, from the confined waters of the Mississippi River at New Orleans and the Houston Ship Channel to the comparatively open water sections of the Delaware, Chesapeake, and Tampa Bays. Two of eleven participating associations, the Association of Maryland pilots and the Bay and River Delaware Pilots, were already well along in installing portable systems with each pilot in their associations. These two associations contributed the majority of data for the evaluation.

In April, 1996, a working group made up of five members of the Cooperative completed a 15 page Evaluation Form designed to address the pertinent evaluation topics, among them:

- The physical characteristics of the units
- The logistical considerations of the units in transport and operation
- The accuracy and usefulness of the information provided by the units
- The comparison between the information provided by the units and information provided by the ship's equipment
- Conditions of use for the units
- The reliability of the units in providing accurate information
- Identification of the most helpful features of the units
- Primary criticisms of the units
- Suggested improvements to the units
- Assessments of the efficiency and safety-related factors for working pilots
- Training considerations for proper unit use
- Effects of the unit on the practice of piloting

These evaluation forms were distributed to the test ports for their earliest completion. The evaluation period was originally established at six months, but was subsequently extended for six more months to accommodate certain test ports experiencing manufacturer delays in getting equipment on the water for evaluation. Some of these ports were never able to get equipment on the water for evaluation.

## EVALUATION RESPONSE

The evaluation was based on responses received from 70 pilots, between June 1996 – June 1997, who used units from four different manufacturers in 11 U.S. ports on a total of 4,125 transits, with a median use of 30 transits each. They responded to a self-administered survey containing 54 questions that included both closed-end and open-end opportunities to respond. The evaluation form contained 12 demographic and environmental variables that described the characteristics and experience of the pilots. It also contained 121 variables that pertained to the physical characteristics and operation of the DGPS units, the presentation and accuracy of information, and the usefulness of the units to various piloting tasks. The form also included 8 open-ended questions asking for summary conclusions and observations about the units.

The responses showed a very high degree of agreement on most questions. The pilots who have used DGPS units have substantially similar experiences. Younger pilots agreed with older ones. Relatively new pilots agreed with much more experienced ones. Those who have used the units for many transits agreed with those who have used the units for only a few transits. Analysis of subgroups revealed no statistically significant differences when comparing pilots on age, years of experience, number of transits with the unit, types of waterway piloted, or type of unit used. This correlation is not surprising given the comparatively small sample size and the fact that most pilots were using the same unit. Further, most of the pilots were operating on the same bodies of water. A larger and more diverse sample would be required for a more valid comparative test of different units, or of the effects of different combinations of age, experience, and circumstances. As such, comparative analysis between the different units and other factor combinations is not provided.

## EVALUATION CONCLUSIONS

Conclusions from the Evaluation findings include:

1) The Portable Electronic Piloting Aid units enhance the safety of piloting.
2) The units provide very accurate position, speed, and chart information, in many cases more accurate than information provided by ship's equipment.
3) The units do not indicate vessel heading with great accuracy, but do indicate course over ground (COG) with great accuracy.
4) The value and usefulness of the units is rated consistently high.
5) Use of the units does not distract the pilot from his traditional duties.
6) The units do not detract from bridge team interaction, but actually improve it.
7) The units are fairly easy to learn to use.
8) Decreasing overall weight is the most frequently cited means of improving the unit.
9) The great majority of evaluating pilots want their units to provide multi-ship information.
10) Wire cables required for unit operation present safety and operational concerns for many pilots.
11) If a ship icon is utilized in any of the unit's programs, it should be to scale.

## ADDITIONAL ANALYSIS AND CONCLUSIONS:

In its overall analysis of PEPA technology, the Vessel Piloting Cooperative Team investigated issues not fully addressed in the Evaluation itself. Included in that analysis were following points:

> While it is clear that 70 U.S. pilots providing evaluations for the study (the majority of whom are from associations already committed to the technology) cannot and do not speak for all U.S. pilots, the fact is that the evaluating pilots are the pilots who have been exposed to working PEPA equipment on the water in actual piloting practice. They are in virtual unanimous agreement in reporting that PEPA technology enhances the safety of their piloting, and give these units very high marks for the accuracy of the information they provide. Although not without criticism and cautious words for the technology and its use, these pilots clearly indicate that PEPA equipment is a helpful tool which aids them in the day-to-day practice of piloting. The equipment provides the pilot with more and better information with which to make decisions, and increases overall confidence in the process, especially in adverse weather situations when other information-providing sources tend to break down (e.g., low visibility in fog, radar in squalls, etc.).
>
> The application of this technology is quite clearly still in its infancy. The technology is advancing quickly. Wireless system components, multi-ship units connected via continuous communication links, improved battery and heading sensor capabilities, improved software features, and smaller sub-notebook, palm-sized equipment are all among developments likely to improve the performance and acceptance of PEPA systems in the near future.

As with the application of any new technology, there will be initial difficulties with PEPA use and development. U.S. pilots are already experiencing some of these difficulties now. Chart data issues, liability considerations, system dependability concerns, establishment of equipment standards, training requirements, and operating procedures are just some of the areas where attention is required now, and will be required in the future.

It is important that this technology should never be used to substitute for or replace the traditional techniques of piloting, but rather should be used only to support them. When properly functioning and used with appropriate caution, PEPA units are best and most properly viewed as a helpful tool which can assist the pilot to safely do his job, providing him information which may aid in his decision making processes. To this end they show great promise; beyond this role they have the potential to do serious harm. Suggestions of these systems replacing channel buoys, of their being used by anyone other than properly trained and experienced pilots, or of their being used to move vessels in prohibitive weather conditions represent misconceptions of the proper role of this technology of potentially grave consequence. The phenomena known as "radar-assisted collision," which vigilant mariners strive constantly on guard against, applies equally well to all applications of PEPA technology.

As PEPA systems are integrated electronic navigation systems which involve processing and displaying a myriad of data from numerous sources, their proper operation requires a knowledge and set of skills which has to be developed in untrained users. Users of PEPA units should possess, among other things, a solid understanding of DGPS and electronic charting, a working fluency with the unit's computer, a precise knowledge of the capabilities and limitations of their PEPA equipment, and a sound grasp of the techniques by which to incorporate the unit to advantage in working practice in a safe manner.

Also worth noting is the sometimes overlooked fact that each port is unique - and each pilot association's operation is correspondingly unique. There is no one ideal PEPA system or application for all U.S. ports. Any application of PEPA technology in a given port is best evaluated and considered by the pilots of that port. Not only are pilots the prospective users of the technology, they are the population in the best position to determine how it might provide an enhancement to safety and efficiency of ship movement in their port.

From the Cooperative Team's overall analysis of the technology, additional conclusions were drawn. The Additional Conclusions drawn from that analysis include the following:

12) As pilot associations acquire units for their port, it is important that a common standard of chart data be utilized in that port.

13) Portable Electronic Piloting Aid Units should never be used to substitute for or replace the traditional techniques of piloting, but rather be used only to support them.

14) Training in the proper use of the units and the technology they utilize is strongly encouraged.

15) For those pilot associations utilizing PEPA systems, an ongoing maintenance program should be established by which the accuracy and proper operation of the individual PEPA units are periodically verified.

16) Any application of PEPA technology in a given port is best evaluated and considered by the pilots and pilot association of that port.

17) The exchange of knowledge and experience with PEPA technology among U.S. piloting associations and PEPA system providers has enhanced safe ship piloting practice and should continue as the technology develops.

# A SUMMARY REPORT OF THE *VESSEL PILOTING COOPERATIVE PROGRAM'S PORTABLE ELECTRONIC PILOTING AID PROJECT*

## Editor:

Vincent Kirby

## Contributors:

Wayne Bailey and Joseph Bradley, Carl Bowler, Joseph Frees, Frederick Ganjon, James Maida, Andrew McGovern, Richard Morrison, Chuck Parker, David Petraszewski, Larry Simpson, Donald Sytsma, Brian Tahaney, Daniel Waldeck, Joseph Warfield, Colin Weeks, Donald Willecke

## Abstract:

This report describes the activity and findings of the Vessel Piloting Cooperative's Evaluation Project of Portable Electronic Piloting Aid (PEPA) systems for ship pilots[1].

Technological developments in the field of navigational technology, including electronic charting and Differential Global Positioning Systems (DGPS), have made possible the manufacture of highly-accurate, carry-aboard navigational computers designed specifically for use by ship pilots. These units, and the systems which support them, have the capability of providing pilots with information of accuracy and utility unmatched by shipboard sources. Over a two year period, the Piloting Cooperative's forum, the APA Navigation & Technology Committee, with assistance of the Volpe National Transportation Systems Center and the U.S. Maritime Administration, conducted a multi-step project designed to investigate this technology and its utility for the practice of piloting. The study team: solicited participation from all known and interested PEPA manufacturers; encouraged the development of prototype units for a set of test ports throughout the country; monitored the implementation of the most promising systems in the test ports; and conducted trials and evaluation of the equipment through survey and personal assessment by working pilots. From the evaluation data gathered, the study team formulated a set of conclusions to enhance the application and improvement of PEPA technology. From analysis of the overall project and issues not fully addressed in the Evaluation data, the study team formulated a set of additional conclusions to further enhance the application and improvement of PEPA technology.

[1] The Vessel Piloting Cooperative is a government/industry Research and Development program coordinated by the American Pilots Association's Navigation & Technology Committee and supported by the U.S. Maritime Administration. The Cooperative's mission is to conduct research activity which enhances safety and efficiency in U.S. piloting operations.

# TABLE OF CONTENTS

# PREFACE

Contributions for this report came from personnel affiliated with the Volpe National Transportation Systems Center (VNTSC), the National Oceanic and Atmospheric Administration (NOAA), the American Pilots Association (APA), numerous U.S. piloting associations, and various manufacturers of PEPA systems.

The conclusions contained herein are those of the authors and the Vessel Piloting Cooperative, and should not be construed as official policy of the APA, VNTSC, NOAA, U.S. Maritime Administration, or any individual U.S. piloting association.

# SUMMARY REPORT SECTION OVERVIEW

**Section 1, INTRODUCTION**, describes the origin, background, and scope of the Vessel Piloting Cooperative Program and the Portable Electronic Piloting Aid Project.

**Section 2, SUPPORTING TECHNOLOGY**, provides a basic explanation of two enabling technologies which support PEPA applications, the Differential Global Positioning System and Electronic Charting.

**Section 3, MANUFACTURER INFORMATION**, offers manufacturer descriptions of currently operational PEPA systems.

**Section 4, MULTI SHIP APPLICATIONS**, introduces the concepts of multi ship PEPA systems, with specific emphasis on communication solutions for linking individual units.

**Section 5, PILOT ASSOCIATION REPORTS**, consists of contributions from individual U.S. pilots describing their Pilot Associations' experience in considering, installing, and evaluating PEPA technology in their individual ports.

**Section 6, EVALUATION**, describes the Portable Electronic Piloting Aid Evaluation in its entirety, including findings and conclusions.

**Section 7, CONCLUDING REMARKS**, discusses issues raised with the advent of PEPA systems not directly addressed in the Evaluation and offers some Additional Conclusions therefrom.

# Vessel Piloting Cooperative Team

## American Pilots Association

Captain Jack Sparks, President
Mr. Paul Kirchner, Executive Director-General Counsel
Ms. Lisa Kates, Assistant Secretary

## APA Navigation & Technology Committee

Captain Carl E. Bowler, Chairman; San Francisco Bar Pilots Assoc.
Captain Andrew McGovern, Vice Chairman; Sandy Hook Pilots Assoc.
Captain John Atchison; Cumberland Sound Pilots Assoc.
Captain Richard Beebe; Pilots' Association for Bay and River Delaware
Captain Douglas Grubbs; Crescent River Port Pilots Assoc.
Captain Scott Loga; Crescent River Port Pilots Assoc.
Captain Richard Morrison: Association of Maryland Pilots
Captain Richard Owen; Association of Maryland Pilots
Captain Joseph W. Warfield; Houston Pilots
Captain Donald Willecke; Western Great Lakes Pilots Assoc.

## U.S. Maritime Administration

Mr. Alexander C. Landsburg; Program Manager, Systems Safety and Human Factors
Office of Maritime Labor, Training and Safety

## Volpe National Transportation Systems Center

Mr. Vincent Kirby
Independent Marine Consultant

# 1
# INTRODUCTION

In March of 1995, a cooperative agreement was signed between the American Pilots' Association (APA) and the U.S. Maritime Administration (MARAD). The agreement established a profession-led cooperative Research and Development program. The mission of the Piloting Cooperative was identified as defining and conducting R&D projects determined to enhance safety and efficiency in U.S. piloting operations. The focus of the Cooperative was established as pilot-identified and prioritized research projects which U.S. pilots consider to be of the greatest potential benefit to the profession. The APA's Navigation and Technology Committee became the coordinating forum for the Cooperative, providing the necessary expertise in refining project ideas and guiding project development. A modest level of direct funding was provided by MARAD for project efforts, including coordinating and technical assistance provided by the Volpe National Transportation Systems Center (VNTSC).

From the beginning of the Cooperative's consideration of various research projects, it was clear there was strong interest and support for an investigation of "carry-aboard" navigational computers. A number of developments in navigational technology had combined to make possible a first generation of portable electronic piloting aid systems designed specifically for use by marine pilots. A couple of these portable electronic piloting aid (PEPA) units were entering the marketplace, and a number of manufacturers were considering the design of prototype units for this market. Manufacturers claimed a wide range of capabilities for their systems. Some systems required the utilization of emerging technology not yet adapted for commercial marine application. It was obvious to the Cooperative Team that both the utility and reliability of this technology required evaluation, as well as its impact on the practice of piloting itself. The Cooperative designated the evaluation of portable electronic piloting systems as its first project.

## 1.1 OBJECTIVES

The objectives of the Portable Electronic Piloting Aid Project were:

- To facilitate research and development in the area of portable electronic piloting systems through assessment of the state-of-the-art and evaluation of various portable electronic navigation aid systems for piloting purposes.
- To encourage exchange of information and experience with PEPA technology among U.S. piloting associations, current and potential manufacturers of PEPA equipment, and the maritime community at large.
- To assess the utility of the technology as it currently exists and to gain insight into the impact of this technology on the practice of piloting.

## 1.2 SCOPE

The findings and conclusions of this report provide a framework to assist pilots, manufacturers, and the maritime public at large in the utilization and improvement of PEPA technology.

## 1.3 EVALUATION PARTICIPANTS

The Cooperative Team involved a range of manufacturers and ports in its evaluation.

On July 20, 1995, ten manufacturers of Differential GPS Portable Piloting Aid systems were invited to participate in this project. They included:

**ASTRONAUTICS CORP. OF AMERICA, Milwaukee, WI**
**DF CRANE ASSOCIATES, INC., San Diego, CA**
**ELECTRONIC MARINE SYSTEMS, INC., Rahway, NJ**
**HYDROGRAPHICS ASSOCIATES, INC., Houston, TX**
**JJM SYSTEMS INC., Ivyland, PA**
**NORTHSTAR TECHNOLOGIES, Acton, MA**
**OCEANA ADVANCED INDUSTRIES, Petach-Tikva, Israel**
**ROSS ENGINEERING, Largo, FL**
**STARLINK/RAYTHEON C/O RAYTHEON SERVICE CO., Mt. Laurel, NJ**
**TRIMBLE NAVIGATION, Middletown, RI**

Subsequent to that date, contact was made with:

**ARINC, Annapolis, MD**
**CYBERNAUTICS, Largo, FL**
**LOPOS, Hamburg, Germany**
**METEOR COMMUNICATIONS, Kent, WA**
**OFFSHORE SYSTEMS LTD., North Vancouver, BC, Canada**

Piloting associations participating in the evaluation included:

**ARANSAS-CORPUS CHRISTI PILOTS, Port Aransas, TX**
**ASSOCIATION OF MARYLAND PILOTS, Baltimore, MD**
**BRAZOS PILOTS ASSOCIATION, Freeport, TX**
**CHARLESTON BRANCH PILOTS, Charleston, SC**
**CRESCENT RIVER PORT PILOTS ASSOCIATION, Belle Chase, LA (New Orleans)**
**GALVESTON - TEXAS CITY PILOTS, Galveston, TX**
**HOUSTON PILOTS, HOUSTON, TX**
**NEW YORK/NEW JERSEY SANDY HOOK PILOTS, Staten Island, NY**
**NORTHEAST MARINE PILOTS, Newport, RI**
**PILOTS ASSOCIATION FOR THE BAY & RIVER DELAWARE, Philadelphia, PA**
**PUGET SOUND PILOTS, Seattle, WA**
**SAN FRANCISCO BAR PILOTS, San Francisco, CA**
**SOUTHEASTERN ALASKA PILOTS ASSOCIATION, Ketchikan, AK**
**SOUTHWEST ALASKA PILOTS ASSOCIATION, Homer, AK**
**TAMPA BAY PILOTS, Tampa, FL**
**WESTERN GREAT LAKES PILOTS ASSOCIATION, Superior, WI**

## 1.4 PROJECT TASKS

The project was broken down into the following tasks:

1) Identify pilot associations and pilotage waterways to be involved with the evaluation of portable electronic piloting aids.
2) Identify available technology sources and services for portable Differential GPS navigation units and arrange for the representative pilot associations to acquire units for on-the-job trial, assessment, and evaluation by the piloting associations and their members
3) Identify elements of units to be evaluated and structure these elements into a PEPA Evaluation Form.
4) Perform evaluations of the equipment and its utility for pilotage functions under different conditions through survey and personal assessment; Data to be gathered on the physical characteristics of the units, data sources available, accuracy of the data, presentation formats, methodologies for using the data, ease of use of the unit, value in the aid of piloting, communications issues, general utility, research/design issues, future needs/developments/ recommended improvements, etc.
5) Collect evaluation survey data and assess results, developing a report of the evaluation efforts.
6) Draft a comprehensive report presenting the pilot research program and evaluation results, describing pilot experiences with the equipment, future needs and recommended improvements for navigation and communication technologies for improving safety and efficiency of piloting operations.

# 2
# SUPPORTING TECHNOLOGY

Over the last decade, a number of developments in navigational technology occurred to make possible a first generation of commercially-manufactured portable electronic piloting aid systems designed specifically for use by marine pilots. While a myriad of technology is involved with these systems, two technological developments in particular greatly contributed to the emergence of these piloting aids: the Differential Global Positioning System and Electronic Charting. These two technologies, in conjunction with laptop computer technology, are the principal technologies which are utilized by portable electronic piloting aid (PEPA) systems. Though an exhaustive description of these contributing technologies is not the focus of this report and is covered elsewhere[2], an overview of these technologies and their relationship to PEPA application are presented here.

## 2.1 GPS & DGPS

Most mariners are broadly familiar with the Global Positioning System (GPS) as the Department of Defense satellite-based radionavigation system which uses orbiting satellites to provide accurate and continuous worldwide position fixes. Differential GPS (DGPS) is a positioning system which supplements the operation of GPS with one additional feature: DGPS utilizes all of the signals of the regular Global Positioning System and supplements those signals with an additional correction signal (differential signal) broadcast from a permanent local shore installation. The practical result for the civilian mariner is that the navigational accuracy provided by DGPS is significantly greater than the accuracy provided by the GPS system alone.

## 2.2 GPS

"GPS" is the commonly-used abbreviation for *Navstar GPS,* which itself stands for *Navigation Satellite Timing and Ranging Global Positioning System.* Developed and operated by the Department of Defense, GPS consists of 24 operational satellites in six circular orbits 20,200km (10,900nm) above the earth at an inclination angle of 55 degrees to the equator with an 11 hour 56 minute period[3]. The satellites continuously broadcast position and time data; allowing land, sea, and airborne users to determine their three-dimensional position[4], velocity, and time 24 hours a day, in all weather, anywhere in the world with a precision and accuracy exceeding that of other traditional radionavigation systems. The satellites are spaced in orbit so that at any time a minimum of six satellites are in view to users anywhere in the world.

Constantly monitoring the satellites in the GPS system is the GPS central control station at Falcon Air Force Station in Colorado Springs, CO, supported by five monitor stations and three

---

[2] See References

[3] *GPS Facts & Figures,* USCG Navigation Center, Navigation Information Service, Alexandria, VA, October, 1994. Hall, G., and Schelechte, G., *USCG Differential GPS Navigation Service; Operational In 1996?*, USCG Navigation Center, Navigation Information Service, Alexandria, VA..

[4] The marine navigator generally has need for position information in only two dimensions, the horizontal dimensions of latitude and longitude. For this positioning a minimum of three satellites in view is required.

ground antennas located at various points in the world[5]. The monitor stations track all of the GPS satellites in view and collect ranging information from the broadcasting satellites. The monitor stations feed the collected information back to Colorado Springs, where extremely precise satellite orbits are computed. Updated navigational messages and information are then transmitted to the individual satellites via the ground antennas, which are themselves constantly transmitting and receiving satellite control and monitoring signals.

A GPS receiver, with its antenna and processor, receives the GPS satellite broadcasts and computes precise position, velocity, and time information. The principle employed in this positioning involves the concept of satellite ranging. The receiver figures its position on earth by measuring its distance from the group of satellites in space. The satellites act as precise reference points, each transmitting an accurate position and time signal. The receiver measures the time delay for the signal to reach the receiver, which is the direct measure of the apparent range to the satellite. Measurements collected simultaneously from four or more satellites are processed to solve for the three factors of the three-dimension position, velocity, and time; three satellites are needed to process two dimension position, velocity, and time.

Complicating the GPS picture somewhat is a Department of Defense operating policy which currently breaks the GPS system down into two levels of navigational accuracy: one, an encoded Precise Positioning Service (PPS) (providing a positioning accuracy of 15 to 20 meters) intended almost exclusively for military and official government use, and two, a Standard Positioning Service (SPS) (providing a positional accuracy of 20 to 40 meters) for general public and industry use. Citing U.S. national security interests, the U.S. government intentionally introduces errors into the SPS, using a process called Selective Availability (SA). SA in effect degrades the accuracy of the system's full capabilities by deliberately skewing satellite signals at random times. Including all of the induced errors, SPS provides positional accuracy to the mariner to within 100 meters (2 drms-distance root mean square[6]) at 95% probability (340 nanoseconds time). This lesser accuracy is adequate for most offshore navigation applications, but it is not sufficient for most coastal/piloting applications. In close proximity to land and in confined waterways precise navigational accuracy is required.

Numerous systems have been developed or proposed to augment the performance of GPS, with different applications in mind, including marine, aviation, land, and survey applications.[7] These differing systems employ various architecture configurations and different techniques to upgrade the accuracy of the Global Positioning System. For coastal marine navigation, the augmented GPS system, which emerged as the most practical, was the U.S. Coast Guard's radiobeacon-based Differential Global Positioning System (DGPS).

[5] Monitor stations: Hawaii, Colorado, Ascension Island, Diego Garcia, Kwajalein; Antennas: Ascension Island, Diego Garcia, Kwajalein.

[6] Distance Root Mean Square (drms) is a measurement of accuracy derived by taking twice the square root of the sum of the squares of all of the radial errors surrounding the true point divided by the total number of measurements. In other words, fixes have a 95% probability of falling within a given circle (of 100 meters in this case) from the true location at its center.

[7] U.S. Department of Commerce, National Technical Information Service Institute for Telecommunications Sciences, NTIS Special Publication 94-30,*A Technical Report to the Secretary of Transportation on a National Approach to Augmented GPS Services*, Boulder, CO, December 1994.

## 2.3 DGPS

In 1987, the U.S. Coast Guard Research & Development Center in Groton, Connecticut, sought to meet this need for greater coastal accuracy. A team began conducting research and testing of differential techniques to enhance GPS accuracy for coastal navigation applications. Their project sought to provide a precise radionavigation service which meets the accuracy, availability, integrity, and reliability requirements for harbor and harbor approach navigation. The differential technique they employed involves installing very sensitive navigation equipment at a precisely known location to receive the GPS satellite signals. This equipment then compares the position solution from the received signals to its (already known) exact position. The result of this comparison is then generated in the form of a correction message and is sent to local users within range via radiobeacon broadcast.

A high-quality GPS receiver, called a Reference Station, is positioned at an accurately surveyed shore installation, e.g., Montauk Point, NY, to cover the entire NY navigation area. For each satellite "in view", the Reference Station 1) receives the satellite's signal, 2) processes a position from that signal, 3) compares that position with the exact "true" position of the installation, and 4) calculates an individual error correction for each satellite. All of the corrections for all of the satellites then "in view" are then broadcast "horizontally" via high-powered marine beacons to any ships within beacon range.

The users' DGPS receivers collect navigational signals from all satellites in view, plus the differential corrections from a DGPS beacon in the region. [Many DGPS receivers consist of two units: a DGPS beacon radio receiver which can receive the error correction signal, and a GPS receiver with a data port for the DGPS corrections, which can process and display the corrected information.] The receivers then display position, velocity, and time information with markedly improved accuracy over the GPS system without the corrections.

## 2.4 DGPS ACCURACY

The U.S. Coast Guard's published accuracy improvement (2drms) is 10 meters or better for DGPS (USCG signals) compared to the 100 meters or better figure cited earlier for GPS (Standard Positioning Service). Working accuracies of 3 meters or better are commonly cited by users as the norm. Additionally, an integrity improvement is realized as each GPS satellite's signal is independently checked and evaluated.

## 2.5 THE DEVELOPMENT OF ELECTRONIC CHARTING TECHNOLOGY 1984 - 1997

The following sections on Electronic Charting (sections 2.5 - 2.10) are a contribution provided for this report by Frederick K. Ganjon, J.D., former Executive Director, Office of Coast Survey, National Oceanic and Atmospheric Administration.

### BACKGROUND

The concept of electronic charts has existed for a number of years, but it was not practical to accomplish until the advent of powerful and relatively inexpensive microcomputers in the 1980's and 1990's. Furthermore, it was not possible to achieve the full benefit of electronic chart technology without a world-wide, high accuracy satellite positioning system such as Global Positioning System (GPS), or more particularly, Differential Global Positioning System (DGPS). For the maritime community electronic charting and DGPS are mutually beneficial technologies in the sense that the mariner cannot obtain the full potential of one without the other. DGPS can provide the ship's position with sub-meter accuracies, but if the mariner has to manually plot that position on a paper chart, he loses the benefit of the accuracy because he has moved from that position long before the manual plotting has been completed. On the other hand, electronic chart technology can show a plot of the ship's position in real time, but without the accuracies of DGPS, the benefit of this real-time knowledge of position is diminished.

As the electronic chart technology has developed, several distinct variations have evolved. At the top end is the Electronic Chart Display and Information System (ECDIS). ECDIS was originally planned to include everything necessary to legally replace the paper charts that ships are required to carry by the Safety of Life at Sea (SOLAS) Convention of 1974. In fact, the ECDIS standards define a system that has much more functionality than any paper chart.

ECDIS has a well defined list of functions and is required to use vector format nautical chart data provided on the authority of a national Hydrographic Office. Any device which uses electronic chart technology but does not meet the standards of ECDIS, including the full list of functions and the use of the appropriate vector format data, is called an Electronic Chart System (ECS). There is a full range of ECS devices in the marketplace, ranging from very complex and usually expensive systems which meet the ECDIS standards, to very simple and inexpensive systems which perform only the most rudimentary functions.

One basic way to distinguish ECS/ECDIS units is by the types of data they use. Some systems use raster data. The term "raster" refers to a video image that is similar to a picture. The information is provided visually to the user, and the computer generally cannot interrogate the data. Other systems user vector data. With vector data, every point or line in the data set is identified by a series of attributes. At the same time the user views the resulting image, the computer can interrogate the attributes of the entire data set, even those data beyond the immediate view of the user. In this way, the system can be programmed to alert the user about information which may not be apparent to him from what he can see on the monitor. The standards that have been developed for ECDIS require the use of vector data.

## 2.6 ORIGINS: FROM PAPER CHARTS TO ECDIS

Mariners have been using paper nautical charts for hundreds of years, and they have become the mariner's primary aid to navigation. As paper charts evolved, more and more information was added. Putting all of this information on the paper chart in a clear way that did not look cluttered and did not confuse the mariner became a challenge to cartographers. Symbols were created as a means to graphically relate information in a concise way. In some cases, abbreviated text notes were developed to provide the mariner with additional information associated with some of the data symbols, such as the sounds and lights for buoys. This development of the paper nautical chart was not uniform throughout the world and different nations ended up with different techniques and procedures. From time to time, for the safety of navigation, the various chart producing nations would get together to share practices and technologies. However, it was not until this century that the major chart producing nations joined together to formalize this collaboration by establishing the International Hydrographic Organization (IHO).

One of the primary purposes of IHO was to develop standards for producing nautical charts and keeping them up-to-date, so that mariners would have reasonable assurances of the accuracy and dependability of a chart purchased anywhere in the world. IHO has developed standards for hydrographic surveys, chart symbols, chart projections, chart borders, and a number of other issues related to chart production. With this history, it was not unexpected that IHO would take an interest in the development of electronic charts. IHO established a committee to work on electronic chart technologies in 1986. IHO has now developed chart content and display requirements for ECDIS (IHO Publication -52) as well as a transfer standard for digital hydrographic data (IHO Publication S-57) that is the basis for the vector data format used by ECDIS. Included in IHO S-57 is an ECDIS [data base] Product Specification.

While IHO has set the standards about how nautical charts are produced, it has been the International Maritime Organization (IMO), under the United Nations, that has set the standards about how nautical equipment and devices, including nautical charts, are used. In the paper chart world, the relationship between IHO and IMO was reasonably clear and their respective responsibilities were defined. However, in the electronic chart world, there appeared to be overlaps in the traditional areas of responsibility. As a consequence, IHO and IMO formed a joint committee, the Harmonization Group on ECDIS (HGE), to work on the standards for production **and** use of electronic charts.

The HGE developed Performance Standards for ECDIS which were subject to rigorous testing by a number of nations over a period of several years. The most active countries in the development and testing process included Australia, Canada, Denmark, France, Germany, Japan, Netherlands, Norway, Russia, Sweden, United Kingdom, and the U.S.A. After final revisions based on the experience gained during the period of testing, these performance standards were adopted by the IMO Assembly in 1995 and issued as IMO Resolution A19/Res.817. Both IHO S-52 and S-57 are specified in this IMO performance standard.

At the request of IMO the International Electrotechnical Commission (IEC) has been working to develop methods for testing the operational and performance requirements of ECDIS. This effort started in 1992 and is expected to be completed in mid-1997. This IEC document will become the basis for type approval specifications for an IMO-compliant ECDIS.

## 2.7 WHAT IS ECDIS ?

The term ECDIS was originally defined by IHO and later refined by the IMO and HGE. All of the individuals and organizations involved with the initial definition and the subsequent standards development wanted a system that would be able to replace paper nautical charts. In doing so, the ECDIS would have to provide for maritime safety without compromising any of the performance that already existed with paper charts. These objectives were summarized in the HGE terms of reference which have been incorporated in the Introduction to the IMO Performance Standards as follows:

- The primary function of the ECDIS is to contribute to safe navigation.
- ECDIS with adequate back-up arrangements may be accepted as complying with the up-to-date charts required by regulation V/20 of the 1974 SOLAS Convention.
- In addition to the general requirements for shipborn radio equipment forming part of the global maritime distress and safety system (GMDSS) and for electronic navigational aids contained in IMO resolution A.694(17), ECDIS should meet the requirements of this performance standard.
- ECDIS should be capable of displaying all chart information necessary for safe and efficient navigation originated by, and distributed on the authority of, government authorized hydrographic offices.
- ECDIS should facilitate simple and reliable updating of the electronic navigational chart.
- ECDIS should reduce the navigational workload compared to using the paper chart. It should enable the mariner to execute in a convenient and timely manner all route planning, route monitoring and positioning currently performed on paper charts. It should be capable of continuously plotting the ship's position.
- ECDIS should have at least the same reliability and availability of presentation as the paper chart published by government authorized hydrographic offices.
- ECDIS should provide appropriate alarms and indications with respect to the information displayed or malfunction of the equipment.

ECDIS is required to use vector format nautical chart data provided on the authority of a Hydrographic Office. The present performance standards and product specifications describe a system that will allow the mariner to select for display those nautical chart data that are most significant for him. Since paper charts are designed to serve a wide variety of users, providing all of the information that is necessary for each type of user, most mariners can identify data or even classes of data that have little of no value for his class of vessel. The ability to selectively remove these extraneous data makes the resulting chart more clear and easier to use. With a few restrictions, ECDIS allows the mariner to reduce his display to just the data that is of interest to him. Furthermore, if he needs the other data at some later time, he can immediately recover all of the original data with just a single switch.

ECDIS provides color combinations that do not interfere with other bridge equipment, and allows the user to select the proper brightness setting for the ambient light conditions. The mariner can choose the chart or chart he wants to display from a system catalog which includes all of the chart data bases that are loaded into the system. ECDIS also provides the capability for the computer system to apply all of the Notice to Mariner corrections to these chart data bases, thereby saving the mariner many hours of tedious work. The systems are required to provide the capability for a "North-up" display, but most also offer a "Course-up" option. In addition, most systems provide the capability to integrate radar and ARPA images into the ECDIS display.

ECDIS provides for two basic modes of operation: route planning and route monitoring. When used for route planning, the mariner can identify his waypoints and the system will compute the course and distance between them. The mariner can make annotations on the display to provide additional information for the voyage. For instance, as the ship is approaching a waypoint, the system can be used to provide a prompt at the desired wheelover point, indicating the rudder angle and rpm's to be used. If the planned route crosses the pre-identified safety depth contour for the ship, or if the planned route crosses into a restricted area, the system will provide a reminder to alert the mariner. Even after the ship is underway, the mariner can always return to the route planning mode and make changes to his planned course.

While the ship is underway, the ECDIS will usually be in the route monitoring mode. The system will monitor the progress of the vessel, providing information such as the heading, the expected arrival time at the next waypoint, the variance from the planned route, and appropriate warnings if the ship approaches any restricted area or is about to cross the ship's safety depth contour. ECDIS is required to provide a true-motion display, which means that the own-ship's position, and other movable data such as radar targets, are shown moving on the earth-fixed chart background. In addition, many systems also provide a relative-motion display where the chart information and such things as radar targets are shown moving relative to the vessel position. While underway, if the vessel moves into an area where a data base is available of larger scale then the data base being displayed by the system, the mariner will be informed.

While the vessel is underway, if the mariner wants to move to the route planning mode of operation to review of adjust his planned route, the ECDIS will continue to monitor the ship's progress and continue to provide warnings to the mariner as may be necessary. The mariner can return to the route monitoring mode with a single operator action.

ECDIS provides a voyage recording device so, for instance, the past track can be reviewed at the change of watch and it provides a means to alert the user to problems such as a systems malfunction or a position system failure. ECDIS requires a back-up arrangement to ensure continued safe navigation if a power failure or a system failure occurs.

Although the developers of ECDIS standards and ECDIS technology tried to anticipate the desires of the mariners, it is expected that many innovations and improvements will occur during the early years of use at sea.

## 2.8 WHERE IS ECDIS?

The IMO Performance Standards were adopted in 1995. At this point, several major marine electronics manufacturers as well as some smaller firms are advertising systems which are described as ECDIS. Several shipping companies have announced that they have purchased and/or installed systems. However, the required hydrographic office data bases for use with ECDIS are extremely limited.

Canada, Japan, and several hydrographic offices in Europe have announced major projects to produce databases in the necessary vector format. However, these efforts have met with mixed success, and very little data is actually available. Part of the problem may be due to recent changes in the IHO vector data format standards, but in general, the vector data have been much more difficult to work with then had been anticipated, involving a greater level of effort and higher costs.

In order to provide data to be used with their systems, several manufacturers have produced vector format nautical chart data for limited geographical areas. These data are generally not as good as that produced by the hydrographic offices, and they do not meet the requirements in the performance standards which allow ECDIS to replace paper charts. However, these data are being used because they are the only data available, and in some cases, the quality is improving.

Considering the cost and level of effort required to produce and maintain a large area vector format data base, and efforts in many countries to reduce the size of government, it is not likely that a world-wide suite of vector format nautical chart data bases will be available before the turn of the century. Until then, even those systems which meet all the other requirements of ECDIS will only be ECS.

## 2.9 THE RASTER FORMAT OPTION

The concept of using raster format data has been around since the beginning of electronic chart technology. At one stage, it was considered to be most desirable, because in raster format the data can be an exact image of the paper chart. When first introduced to electronic charts, some users felt most comfortable with a raster image of the same paper chart that they had been using for years.

One significant disadvantage of raster format data is that the data cannot impart intelligence beyond the visual image itself. Also, at the beginning of the ECDIS standards process in the mid-1980's, raster data was difficult to acquire and it took a large amount of memory. ECS that used raster data took a long time to build the image, and suffered from poor image resolution. At that time, raster format data was very difficult to update other then providing a total file replacement.

In the past few years high speed micro-computers with high resolution monitors and large, inexpensive memories have become common. Raster data is now easy to acquire, easy to work with and can quickly produce a high quality image. In addition, several new software techniques are available to update raster files. There are even some opportunities to add limited vector information to the raster files, thereby allowing the host computer system to assist the user with warnings. As a result, raster based ECS now offer a viable option for navigation.

Since the early 1990's, the National Oceanic and Atmospheric Administration (NOAA) has been using raster image data as part of the paper nautical chart production process. As a result, high quality raster images of the latest editions of all NOAA paper nautical charts are available as a by-product of this process. In 1994, NOAA entered into a Cooperative Research and Development Act (CRADA) agreement with a private sector corporation, BSB Electronic Charts (BSB), to conduct research and development activities related to electronic chart technology. One of the results of this CRADA, combined with the available raster nautical chart images, has been the development of a raster product suitable for use with ECS. By the beginning of 1996, the complete suite of NOAA nautical chart images in raster format was available in the marketplace. These products are produced and marketed by BSB under the authority of NOAA. The chart images are available individually on floppy disk or in geographic packages on CD-ROMs. BSB makes new versions of these images at frequent intervals to include the latest editions of the NOAA paper charts, and offers an update service every 45 days which includes new editions and Notice to Mariner changes. New development work being done under the CRADA is expected to result in a weekly update service in early 1997.

The British Admiralty (BA) also offers raster nautical charts through their Admiralty Raster Chart Service (ARCS). This service provides encrypted images of a worldwide suite of BA charts and an update service. Several hardware manufacturers provide equipment which use these data sets.

At the July, 1996 meeting of the IMO Subcommittee on the Safety of Navigation, the United Kingdom and Netherlands submitted performance standards for a proposed Raster Chart Display System (RCDS) which would allow mariners to use raster format nautical chart data in place of paper nautical charts to satisfy the requirements of SOLAS. The benefit of this proposal was that mariners would be able to take advantage of the high quality raster-based systems that are now available while waiting for the availability of vector format data. The United States supported this proposal, but it was decided that more evaluation was necessary, and the proposal was sent to the HGE for additional work. It is expected that a new, refined proposal will be submitted to IMO again in 1997. It is likely that this new proposal will lead to the development and adoption of performance standards for a system that is fully ECDIS compliant, but will allow the use of raster format nautical chart images, in the manner proposed for RCDS, where and when the vector format data required by ECDIS is not available.

## 2.10 ELECTRONIC CHARTS: SUMMARY

The progress made with electronic chart technology in the past decade has been dramatic and the future is even brighter. The world maritime community has developed performance standards for ECDIS and such systems have been demonstrated. When fully implemented, these systems, used in conjunction with GPS and DGPS, will represent a most significant improvement to maritime safety. As data becomes available in vector format, ECDIS units will be found on more and more vessels. Although the development of a worldwide suite of vector data is likely to be a lengthy process, it is possible that a combination of vector and raster technology may offer an option that will allow mariners to use electronic chart technology right away.

When electronic chart technology is actually in use, the experience gained by mariners will be translated into system improvements that will make the equipment easier to use and more functional. It is also likely that the relationship between electronic charts and GPS/DGPS will continue to expand and improve. One probable innovation will be the use of a vertical component of DGPS to provide real time water level information. It is also probable that electronic chart information will become a major component of Vessel Traffic Information Systems and Vessel Traffic Management Systems.

# 3
# MANUFACTURER INFORMATION

## 3.1 INTRODUCTION

At the commencement of the Vessel Piloting Cooperative's PEPA Project, a number of manufacturers were notified of the project and encouraged to participate. Some of these manufacturers already had working units on the water or prototype units ready for trial; other manufacturers had systems in the design stage. Many system performance claims were made by a number of these manufacturers to pilot associations and the pilot population at large. Some of these claims were fulfilled by the manufacturers - others were not. Relationships were formed between specific pilot associations and specific manufacturers. These relationships fulfilled the Cooperative's laissez faire goal of empowering individual associations to select and evaluate whatever systems they deemed the best for their specific needs and waterways.

During the course of this project, there was a marked consolidation of manufacturers who remained with the project. Some manufacturers experienced financial trouble unrelated to their involvement in the project and went out of business; others found disfavor among the pilot population for making promises they could not keep and/or for not supporting the associations in the design and evaluation period; other manufacturers offered systems which were simply too expensive; still others withdrew from the market for unidentified reasons. What resulted at the end of the project were a few manufacturers whose equipment was considered worthy of evaluation by U.S. pilot associations who offered service and equipment which was both well supported and operational. Descriptions of three such systems are offered here. Their presence here in no way represents the entire field of viable PEPA manufacturers. They are simply the manufacturer's systems which were most involved in this evaluation project.

## 3.2 THE RAYTHEON/STARLINK PORTABLE DGPS NAVIGATION SYSTEM

This contribution (Section 3.2) by Raytheon Service Company's Mr. Chuck Parker, outlines the background, components, application, and future plans of the Raytheon/Starlink Portable Electronic Piloting Aid.

### OVERVIEW

The Starlink Portable DGPS System uses DGPS technology to provide ship pilots with a simple and reliable navigational tool. It was designed as a cooperative effort by the following:

- The Pilots' Association for the Bay and River Delaware
- The Maryland Pilots' Association
- Raytheon Service Company
- Starlink. Inc.

The pilot associations provided the navigational requirements, Raytheon Service Company provided the service and support, and Starlink provided the GPS and electronics expertise.

The system is highly configurable. There are over 150 software-configurable options, which are pre-configured by Raytheon Service Company to meet the exact needs of a given pilots' association. The system also uses highly accurate surveyed data provided by the US Army Corps of Engineers and controlled by the pilots associations.

Screens have been designed to provide the exact information pilots need, without any extra clutter.

One important feature of the system is that it displays its operational status, including normal operation and alarm conditions.

Over 100 Starlink Pilot Portable DGFS Systems are currently in use. Most of the units have been in the field for 2.5 years with excellent performance reviews. The following organizations are using the systems:

- Charleston Branch Pilots' Association
- Hornblower Marine Services (M/V Sassacus)
- High speed ferry between Conn. & New York
- Northeast Marine Pilots
- Maryland Pilots' Association
- MITAGS in Maryland ( Marine Training Facility )
- Sandy Hook Pilots' Association
- Sun Oil Co. 2 - Tankers, Philadelphia & NY Sun
- Virginia Pilots' Association
- Western Great Lakes Pilots Association

Requests for software improvements from these organizations are constantly being serviced by Raytheon Service Company and Starlink.

HARDWARE

The system weighs about 14 pounds, and is transported in a single soft back pack, containing:

- Starlink DNAV-212 DGPS Receiver (contains 2-channel beacon receiver and 12-channel DGPS receiver.)
- Starlink MBA-2 GPS Mini Crossed Loop Antenna with Clamp
- Laptop computer (Upgraded as better laptop PCs become available.)
- 50-foot Antenna Cable
- Versatile AC power supply which operates on all ships' AC power
- Interface cables

SOFTWARE

The system software is comprised primarily of the wheelhouse program and the data files it uses.

The data files are encoded to maintain consistency within a given pilots' association. The data files contain highly accurate information acquired from the US Army Corps of Engineers and the US Coast Guard.

The Wheelhouse program runs on a laptop PC and communicates via the PC's RS-232 serial channel to the DNAV-212. Some of its features are:

- Ship icon showing position and direction of travel on the chart
- Graphical display of the route, with various features such as buoys, bridges, channel edges, and so forth.
- Record, replay, and erase trips
- Mark a position with a single keystroke (one use: 'man overboard')
- ship scaling
- Positional information accurate to within 2 meters, including:
    - system performance alarms
    - cross track distance
    - speed over the ground
    - distance to the next waypoint/turn
    - bearing to the next waypoint/turn
    - course over the ground
    - time to the next waypoint/turn
    - destination ETA
    - satellite information
    - differential GPS correction information
    - dilution of precision information
    - waypoint name
    - range name
    - latitude and longitude
    - local time and date

PLANNED NEW FEATURES

Starlink makes every effort to add requested software features. Following are planned new features:

*USER-DEFINABLE ANNOTATIONS*

The user can use the mouse to select a point on the displayed chart end enter a description to be displayed. The user can also delete the description. For example, the user may want to indicate the location of a dredging operation, and later delete the entry.

*TURNING CIRCLES*

The turning circles work as follows; the pilot enters ship length, width, antenna distance from bow, and minimum margin. Minimum margin is the minimum distance between any part of the ship and the channel edge. It is then up to the pilot to keep the bow circle in front of him inside the channel and the stern circle behind him inside the channel as he maneuvers the ship.

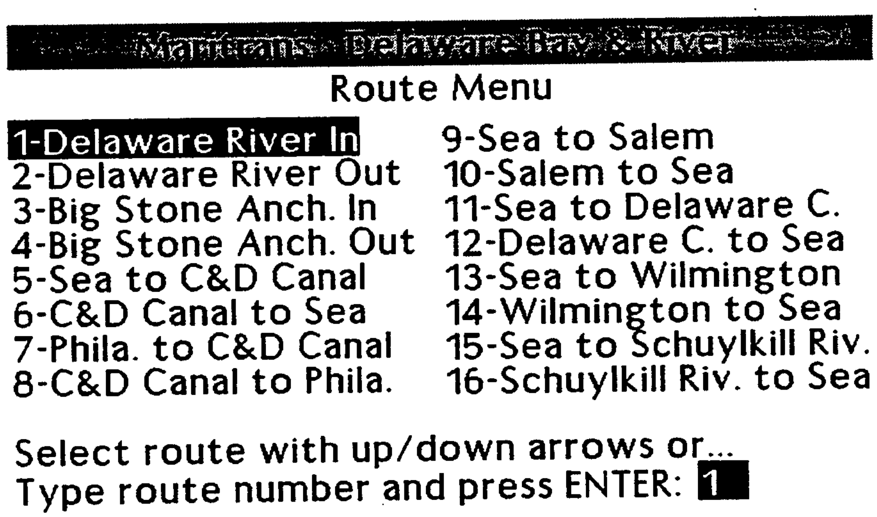
*SATELLITE MAP*

The satellites being tracked by the GPS system are shown graphically, indicating their azimuth and elevation. This can help in telling if satellite signals are being blocked in a particular direction.

*DATA COMMUNICATIONS*

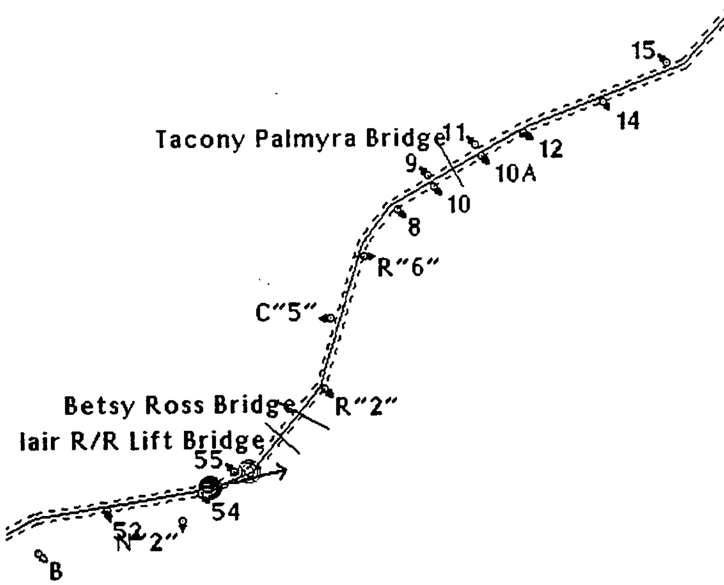
Starlink is considering adding silent VTIS capabilities. Implementations may use VHF and/or a cellular telephone link. Both methods have their advantages and disadvantages, and are relatively easy, technically. The main effort is in determining user needs.

## *Starlink/Raytheon Portable DGPS Navigation System Screens:*



*Starlink/Raytheon Portable DGPS Navigation System Screens cont:*

REPLAY LOG




DGPS

IN TO U3

Fisher Channel

TIME 05:22:29

WED 4 MAR

ETA 07:42

| SATS | |
|---|---|
| Used: 9 | BCN 298.0 |
| Recd: 10 | SS 48 |
| | SNR 10 |
| | AGE 4 |

3.00 min Vector

TTG 00:02

BRG 070°

COG 078°

DIST 1732 FT

SOG 10.5 KT

X L 15 FT

---

DGPS REPLAY LOG

OUT TO Delair Range U4

Ownship LAT N 40° 0' 0.71"
LON W 75° 3' 30.70"

Antenna Offset: 50.00ft. to Port

3.00 min Vector

TTG 00:05

ETA 08:27

TIME 20:00:52

SAT 22 JUN

| BCN | SS | SNR | AGE |
|---|---|---|---|
| 286.0 | 53 | 17 | 3 |

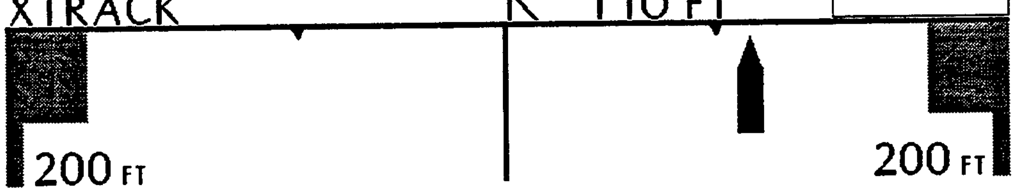
BRG TO WPT 196° COG 199°

DIST 4723 FT

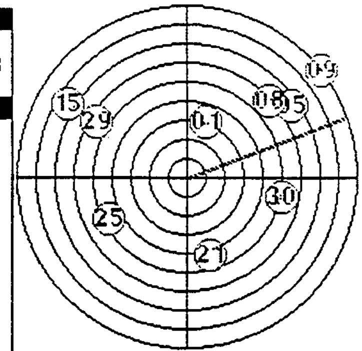
SOG 9.7 KT

XTRACK R 116 FT

GDOP = 1.9
HDOP = 0.9
VDOP = 1.4
TDOP = 0.8



**Operational Status**
3-D differential GPS navigation using 8 satellites
D(3)x8




**Data Source**
LOG FILE: WAYNE001.LOG

**Current Position**
LAT = N 40  0' 59.35200"
LON = W 75  1' 47.61600"
ALT = -52 Feet

COG = 70 Degrees
SPD = 11.2 Knots

TIME= 10:42:23 GMT

**DOP Data** ( Limit )
GDOP = 3.2 ( 6.5 )
PDOP = 2.7
HDOP = 1.3 ( 3.0 )
VDOP = 2.4
TDOP = 1.7

HRRE = 3.6
HACC = 1.2 ( 15 )

VRRE = 6.6
VACC = 4.0

| PRN | AZ | EL | S/N |
|---|---|---|---|
| 1* | 19 | 71 | 51 |
| 5* | 56 | 28 | 31 |
| 8* | 48 | 37 | 41 |
| 9 | 52 | 0 | 16 |
| 15* | 301 | 20 | 41 |
| 21* | 163 | 56 | 36 |
| 25* | 242 | 52 | 41 |
| 29* | 301 | 41 | 40 |
| 30* | 102 | 46 | 43 |

**Reference Station**
Station ID= 10
Health = 0 (0-5 = OK)
Quality = 51%

**Firmware/Software Versions**
GPS Receiver = SG00
BCN Receiver = 0.0
Wheelhouse = v7.01e
Configuration= Mari 7.00d

**Beacon Receiver Data**
Frequency = 298.0
Baud Rate = 200
Strength = 43
Signal SNR= 9
Sferics = 19
Age = 3

**Starlink, Inc.**
6400 HWY. 290 East
Suite 202
Austin, TX 78723-1030
Ph. 512-454-5511
www.starlinkdgps.com

**RTCM Message**

---

DGPS

COG 070.7°

SOG 11.2 Kt

Maritrans - Delaware Bay & River

Control Functions

F1 - Chart
F2 - X-Track
F3 - Dnav Info
F4 - COG/SOG Screen

F11 - Advanced Funcs.
F12 - Control Funcs.

R/W - Read/Write Log
+/- - Fast/Slow Replay
E - Erase Log File

M/Alt-M - Mark/Clear
V - Vector
S - Scale Ship

Q - Quit Program

Esc - Route Menu

U/D - Zoom Up/Down
N/P - Next/Prior Wpt

B - Brightness

T - To Rng/Brg(On/Off)

Alt-O - Reset Ant. Offset
Alt-S - Set Date/Time

---

Maritrans - Delaware Bay & River

Advanced Control Functions

USER-ANNOTATIONS (Not active during Nav)
ALT-A - add an annotation
ALT-D - delete an annotation
ALT-X - re-load deleted annotation

ALT-U - select feet or meters

LOG FILE REPLAY FUNCTIONS:
Left Arrow - Rewind
Right Arrow - Fast Forward
Gray + Key - Replay Faster
Gray - Key - Replay Slower

## 3.3 HANS - THE HOUSTON AREA NAVIGATION SYSTEM – AUGUST, 1997

The following contribution (Section 3.3) from Mr. Colin Weeks, President of HANS manufacturer Hydrographic Associates, describes the background, components, features, and future plans of the HANS Portable Electronic Piloting Aid System.

### INTRODUCTION

HANS, like the systems in daily use by the pilots in Delaware and Chesapeake Bays, is an Electronic Navigation System, one in which position is converted once a second into 'Channel Coordinates' - distance off a channel centerline and distance from one end. This is of particular value to a pilot since the first of these numbers is the electronic equivalent of a Range Line - but one that, in the case of HANS, can be curved as well as straight.

HANS was originally developed 15 years ago to guide hopper dredges - using short range radio positioning - and in that form has been used on all coasts of the U.S. and in most ports. It was modified to accept Differential GPS and was given a four month trial in 1993, aboard a 99,000 ton lightering tanker making bi-weekly transits of the Houston Ship Channel. Both of these systems were interfaced to the ship's gyrocompass and were fully automatic, showing a scaled image of the ship and as well able to work on curves as on straight reaches of the channel.

The earlier systems ran on a computer workstation, which in those days were the only desktop computers with sufficient power. The software was then modified to run on a PC so that a portable version could be developed for pilots. In this form it has been tested by pilots in the ports of Houston, Corpus Christi, Freeport, Galveston and Texas City - but this version is only semi-automatic. Not having a heading input it can only be used in a curved channel if a second pilot is available to input heading through the keyboard.

### HARDWARE

There are two fundamental components, a notebook computer and a DGPS receiver. There is a wide choice of computer since almost any of those on the market today will serve the purpose although an active matrix display is to be preferred, since it provides a wider field of view. On the other hand only one DGPS receiver is recommended for pilot use, the Starlink DNAV-212. It combines in one unit a high quality 12 channel CPS board with a 2 channel beacon receiver, able to switch to a second beacon automatically if the first is lost. The two antennas are also combined so that the pilot has only one antenna cable to run.

The system requires ship's power, either 115 or 240 VAC.

### SOURCES OF DATA

As far as possible, data is taken from the primary source in digital form, thereby avoiding the errors that are inevitable when data is plotted on paper at some stage in its processing. The benefit to the pilot is that the scale of display may be enlarged while docking until the image of the ship almost fills the screen. There is no loss of accuracy if the dock has been digitally defined to similar accuracy to that of the DGPS. Even in dredged channels, there is a significant benefit since the scale of the paper chart is often so small. If the error of a chart is taken as 1 mm on the paper, this can be converted into a distance on the ground by dividing by the natural scale.Thus in the Savannah River, charted by NOAA at 1/40,000, the chart error may legitimately reach 40 meters while the 1/80,000 charts of the Mississippi could have an error approaching 80 meters. This is never a problem in visual navigation where the pilot uses range lines, buoys and beacons provided by the Coast Guard - but when visibility falls he is as blind as everyone else.

HANS channel data is entered from the State Plane coordinates by which the Corps of Engineers (COE) defines the channel to the dredging contractor - and by which the channel is surveyed on completion of dredging. The positions of Aids to Navigation are taken from the Coast Guard's digital files while the positions of docks are taken from land survey data, as in Corpus Christi, or from digital orthophotos (rectified aerial photography) as in the Port of Houston. Dock data taken from such a source is shown in a different color from the river banks so that the pilot knows that he may trust it.

Most of the other data is taken from the paper chart, but it is taken selectively so that only that data is shown which might be of value to the pilot, particularly in an emergency. This might include underwater cables, pipelines, wrecks and obstructions. Where information is available color is used to distinguish between dangers to navigation and hazards to anchoring. Color is also used to distinguish overhead obstructions such as bridges or cables. Where the COE has data on underwater training walls, groins or revetments this also is shown - though such data must often be omitted from the paper chart because of its scale.

It should be noted that depths are not shown on the HANS screen, only the desired route and the limits within which the ship may safely be maneuvered. In a dredged channel these will normally be a line parallel to the channel centerline and the channel toe lines. In a deepwater port they would be routes agreed by the pilots and Coast Guard for inbound and outbound traffic, supplemented by appropriate depth contours.

In Corpus Christi the channel is narrow and ships in their berths will frequently restrict the available width. A special feature provided there allows the pilot to enter the dimensions of a vessel at any of these berths and these will then be shown by white rectangles on the screen.

The system is in use in the form described in Corpus Christi while the Houston system has been upgraded with a new computer and, with a second new system, will shortly be back in use on the Houston Ship Channel.

## INTER VESSEL COMMUNICATIONS

If every pilot in a port carries aboard a computer interfaced to GPS, it is possible to synchronize each computer's clock to the precise time provided by GPS. Each computer can then broadcast its vessel's position, course and speed in succession, without mutual interference, and will be able to display on its own screen every other fitted vessel within radio range. This simple concept has been called HETS, the Houston Electronic Traffic System.

In 1996, a Proof of Concept trial was carried out, to which the Houston Pilots and the Corpus Christi Pilots each contributed their HANS system while the Port of Houston Authority funded the purchase of two radios and two modems. Authority was obtained to use Channel 14 on a temporary, non-interference basis and, since the system had to be easy for a pilot to carry, the shortest antennas available were purchased - 18" whips on a magnetic base. These were one quarter of the wavelength and such antennas require a ground plane in order to function - they are typically used on top of an automobile. When placed on the flying bridge of a ship, however, they are normally surrounded by guard rail stanchions which can both obstruct and reflect the signals. In field trials conducted in Houston, Galveston and Tampa it was never possible to achieve a range greater than 3 miles. The next larger antenna is a half-wave about 36" long. With a base loading coil, it provides both increased gain and freedom from the need for a ground plane

- so it can be mounted on top of the guard rails to gain a greatly increased field of view. Using these antennas a ship outbound from Corpus Christi picked up transmissions from the Pilot Station at 9 miles and signals were exchanged reliably until the Station was abeam.

After discussion with the Houston Pilots, the HANS software has been set up so that if the scale of display is reduced below 1/50,000 - allowing a long view ahead - all detail is removed from the screen apart from the channel toelines and other ships, which at small scales are shown by a numbered green diamond. On pressing a softkey the pilot is prompted to enter the number of one of the diamonds, which causes the display to be redrawn at 1/15,000 centered on the selected vessel. At this scale the image will be drawn true to scale and the pilot can see whether it is a ship or a barge tow, its course and its position in the channel. This is supplemented by a line of data which gives the vessel's name, bearing and distance, course and speed, and its draft.

## RECENT DEVELOPMENTS

Early in 1997, the Johnson Space Center division of NASA offered its services to the Port of Houston Authority under a local outreach program. After some discussion a Memorandum of Agreement, between PHA and JSC, was signed under which the following three projects were agreed:

- The development of a portable system, suitable for a pilot to carry, which would provide both heading and position to a Portable Electronic Piloting Aid. The preferred technology was the use of multiple CPS antennas which can determine heading by measuring differences in carrier phase.
- The development of a low cost system, with similar functionality, for permanent installation in vessels on the inland waterways.
- The further development of HETS, with the immediate objectives of comparing UHF and VHF and of determining the necessity of Forward Error Correction (FEC). HETS requires dedicated simplex frequencies but, since the transceivers would be carried aboard by the pilot, there is no necessity for them to be within the internationally agreed maritime frequency bands. If UHF proves to be a feasible alternative the antenna length is reduced to 11-15", much easier for the pilot to carry.

An important part of this investigation is the development of a hardware timing device that would buffer a computer's output and trigger transmission a required number of milliseconds after a specified timing pulse from the GPS receiver. This would make it easy for all types of system - ECDIS and ECS as well as ENS - to participate.

FEC is a transmission protocol under which redundant data accompanies each message package, allowing the receiver to correct a limited number of corrupted bits. It increases the reliability of reception but at the cost of considerable overhead, which reduces the number of vessels that can use a given frequency. FEC is now rarely used between fixed antennas for that reason, but its use has been found essential when communicating between locomotives, for example. Ships operate at a much lower maximum speed and the necessity for FEC can only be established by theoretical investigations and field trials, both of which NASA is highly qualified to conduct.

The current situation is that NASA has developed an algorithm that will give both heading and roll from two GPS antennas a short distance apart and static trials on one of NASA's rooftops have started. Promising results have been achieved with 20.5" separation and the next series will investigate the possibility of reducing the distance to 12".

THE FUTURE

The full extent of NASA's involvement will depend on the availability of funding for external purchases, which is still being sought, but in any event the results will be public information and available for the developer of any PEPA system. The desired objective of the heading sensor investigation is a watertight unit, sufficiently robust to avoid the need for protection in transit, that would be mounted on the flying bridge to transmit position and heading by radio to the pilot's computer. However there are a number of problem areas to be researched which must be tackled one at a time. At this time it would not appear that a system based on such a unit need exceed the weight of current systems.

The use of HETS for inter-ship communications will only be possible if the FCC recognizes it as a new communications technique and allocates a sufficient number of frequencies, a lengthy procedure - though not as long as if international agreement was necessary but one that has a good chance of success, given support by the Coast Guard. The Dialogue on VTS has stated a need for such communication, not merely between ships carrying pilots but between almost all commercial vessels on the inland waterways. HETS has the potential to provide this capability with a smaller number of frequencies than any technique currently used for VTS communication. The purpose of the NASA trials is to determine the tradeoffs that need to be made in power output, baud rate, bandwidth and error correction so that an eventual application to the FCC may be based on factual data. The optimum factors are being determined for both VHF and UHF so that application may be made for the band that will give the best performance.

HETS (HOUSTON ELECTRONIC TRAFFIC SYSTEM)

The HETS concept only becomes possible when every pilot in a port utilizes a Portable Electronic Piloting Aid in which a computer is interfaced to DGPS. GPS provides all users with a precise timing pulse once a second which can be used to synchronize each computer clock to GPS time. Once this has been done, and a time slot unique to the ship entered, each computer can broadcast the vessel's position, course and speed automatically, without mutual interference and without further operator intervention.

The Port of Houston Authority funded the purchase of 2 modems and 2 VHF radios to allow a Proof of Concept trial. This was conducted in 1996 thanks to the cooperation of the Houston Pilots and the Corpus Christi Pilots who each lent their HANS system. Trials in Houston, Galveston and Tampa proved that, with an 18" quarterwave antenna, signals could not be received at distances over 3 miles. However the substitution of a 36" halfwave antenna allowed reliable communication between a ship and the Corpus Christi Pilot Station at distances up to 9 miles.

The HANS software was set up after discussion with the Houston Pilots. As an example, a pilot passing Redfish Shoal in the Houston Ship Channel, who saw four radar targets in the Bolivar Roads, could decrease the display scale to say 1/150,000 and see four numbered diamonds. On pressing a softkey he would be prompted to enter the number of one of the diamonds. This would result in a display scale of 1/15,000 centered on the selected vessel and showing each ship's outline to scale, with a line of data that would give the name of the selected ship, its bearing and distance, its course, speed and its draft. (If inland waterway vessels cooperate in such a scheme in the future the screen image would show whether it was a ship or a barge tow). In this example the pilot might see that one ship was in the anchorage, another was outbound from Galveston, the third inbound to Texas City, while the fourth target was a barge tow headed towards him. Each vessel broadcasts once a minute but its image is updated once a second by dead reckoning.

The report recommended further trials with two objectives. The first was to investigate the possibility of using UHF in preference to VHF; antenna length is related to frequency and the 36" VHF antennas are cumbersome for a pilot to carry - in comparison a UHF antenna need only be 11-15" long. The second was to investigate the need for Forward Error Correction, a procedure which transmits redundant data in order to correct transmission errors caused by noise and multipath. It had been used during the Corpus Christi trial - and gave high reliability - but substantially reduces the maximum number of users on a given frequency.

The most recent development is that NASA, having offered its services to the Port of Houston Authority in a local outreach program, has agreed to conduct both of these trials and will probably start late in August, 1997. Once a frequency band has been selected - and if the concept is supported by the Coast Guard - it is anticipated that application would be made to the FCC for allocation of five or six dedicated channels that could be used nationwide. One great advantage of the system being carried aboard by the pilot is that no equipment is required in the ship so there is no necessity to remain within the internationally agreed maritime frequency bands.

NASA has also agreed to develop a precise timing device that will make it easy for ECDIS and ECS systems also to participate. With such a device it would be possible for up to 300 simultaneous users to use a single simplex frequency with a 1 minute update rate - unless the trials show that FCC is essential.

HARDWARE COMPONENTS OF THE HANS SYSTEMS SUPPLIED TO THE HOUSTON PILOTS: 6 JUNE 1997

Toshiba notebook computer, Model 110 CT, with 100 MHz Intel Pentium CPU chip with 16KB write-back internal cache 8MB of 3.3 volt 16 Megabit EDO RAM, with 60 ns access time 11.3" (diagonal) active matrix screen with 800 x 600 resolution SVCA graphics controller with 32-bit VL local bus and 1MB Video Ram Accupoint pointing device 772 MB hard disk.

4 year extended warranty.

Starlink DGPS/Beacon Receiver, Model DNAV-212, with dual antenna.

Antenna mount with Vice-Grip and modified Quik-Grip.

115/240 VAC to 12VDC power supply and interconnection cables.

Air-Targus carrying case.

Total weight 18 lbs.

## 3.4 ASTRONAUTICS PORTABLE ECDIS

The following contribution (Section 3.4) from Astronautics Corporation's Kermit Kapp, outlines the components and characteristics of the Astronautics Portable Electronic Piloting Aid.

### OVERVIEW

The basic Astronautics Portable ECDIS a commercially available Notebook Computer with an 80486DX4/75 MHz or greater Processor, 500 MB Hard Drive and 8 MB Ram. The basic configuration provides a 9.5" diagonal screen, however, larger or smaller screens are available upon request This Portable ECDIS computer is equipped with a 3.5" floppy drive, a PCMCIA card slot with a Differential Global Positioning System (GPS) card, external GPS antenna, and an Active Matrix Liquid Crystal Display (AMLCD). Available options involve the processor, hard drive size, display screen size, external extended life battery, docking station, and CD-ROM player. The table provided below describes the basic and optional components of the Astronautics Portable ECDIS.

*Astronautics Portable ECDIS Configuration*

| BASIC SYSTEM COMPONENTS | OPTIONAL (CHARACTERISTICS/COMPONENTS) |
|---|---|
| **Note Book Computer**<br>- 80486DX4 75 MHz<br>- 500 MB hard drive<br>- 8 MB RAM<br>- 3.5" floppy drive<br>- PCMCIA card slot with DGPS<br>- 9.5" AMLCD screen<br>- Integrated trackball | **Ruggedized Computer**<br>- Processor: DX2 or 4, 66/100 MHz<br>- Tailored to user requirement<br>- 16MB<br>- CD-ROM drive<br>- GPS without differential<br>- Dual scan, or 10.4" AMLCD<br>- External trackball |
| **Peripheral Components**<br>- DX-90 chart of desired port<br>- Carrying case<br>- Power adapter (110 or 220V) | **Optional Peripherals**<br>- DX-90 charts of larger areas<br>- External, extended battery<br>- CD-ROM player<br>- Radio/Modem<br>- Shore-based printer or plotter |

### FUNCTIONS

The "own-ship" position is represented by a circle with an arrow depicting heading and the position the ship will be in 6 minutes at the present heading and speed. This representation can be displayed to scale. The Astronautics ECDIS updates the position of the ship every five (5) seconds.

The Heading of the ship is presented on the screen in two ways. The first is the heading vector (or arrow) originating from the own-ship symbol, and the second is a digital readout of the Heading Selected, the Course Made Good (if drift vector factors are available), and the recommended Heading to return to the Heading Selected. The system can store more than 100 waypoints and 20 routes. The ECDIS can record routes for up to 12 hours. Additional features include:

- Graphic and textual hydrographic data
- Navigation aids

- Heading, course, range, bearing and speed information
- Actual and predicted course
- Recommended course and speed
- Cross track distance
- Post track
- Distance/time to go

## CHARTS

Currently, the Astronautics ECDIS uses a vector format in conjunction with the DX-90 chart data base and from additional information that is entered as a template by the pilot. An optional raster/vector hybrid format can be provided to display additional scanned nautical charts or berthing maps. The Astronautics ECDIS can display channel centerline and channel limits in addition to cross track distance information. Both visual and audio warnings are available when a safety margin is exceeded for a ship approaching these limits or the limits of a pre-defined navigation corridor. The scalable chart display can be seen in day or night operation mode. In addition, chart overlays can be manually created.

## COMMUNICATION

Astronautics Console ECDIS provides communication to other ships or shore locations, but the basic configuration of the Portable ECDIS does not provide this capability. With the addition of a commercially available optional Radio/Modem, this capability can be provided. The data is sent via an HF signal that is received by the radio and inputted to the ECDIS computer via an RS-232 port.

## POWER REQUIREMENTS

The Portable ECDIS is provided with a battery for 1 to 2 hours of operation. In addition, the system has a power cord and adapter that allow use of either 115V or 220V DC power from a standard outlet if available. Adapter plugs can also be provided upon request for international plug configurations. The internal system battery operates for a period of 1 to 2 hours in full operation mode due to the high power required for the graphics of the ECDIS. Dual internal battery, or optional external battery configurations can be provided. The batteries can be charged in a period of 1 hour by plugging the adapter and power cord into any standard outlet.

SYSTEM SIZE

The Astronautics Portable ECDIS is transportable. It is provided with a hard-shell watertight carrying case to enable the pilot to easily transport the system onto a ship. The total weight of the Portable ECDIS is based on the level of ruggedization. The weights for the various configurations are provided in the following table.

*ECDIS Weight*

| Configuration | Ruggedized | Non-Ruggedized |
|---|---|---|
| Computer | 13 lbs | 8 lbs |
| GPS | .2 lbs | 1.5 lbs |
| Differential Receiver | .77 lbs | included above |
| Carrying Case | 1.8 lbs | 1.8 lbs |
| **Total Weight** | **15.77 lbs** | **11.3 lbs** |

HARDWARE AND SOFTWARE

The Astronautics ECDIS has an open architecture system readily interchangeable with those of other manufacturers. The entirely commercial-off-the-shelf (COTS) hardware configuration allows individual tailoring for maximum use of available hardware. Only the ECDIS software is developed by and proprietary to Astronautics, the hardware is entirely off-the-shelf, commercially available hardware from any of several producers. The software is transportable between computers subject to the software licensing restriction. Pilots can enter waypoints and either permanent or temporary chart data. Pilots can also adapt the system to contain additional information unique to a port (berthing data, tide schedules, etc...) or general information such as Maritime Regulations in electronic format..

AVAILABILITY

The ECDIS software and hardware are immediately available with a one (1) week delivery (depending on the chart requirements and availability). The operation of a system at a given port is subject to the availability of the necessary DX-90 chart. If a DX-90 chart is not available from NOAA or a given Port Authority, Astronautics can contract a Hydrographic Office to produce such a chart upon demand.

RUGGEDIZATION

The optional ruggedized Portable ECDIS, with a cast aluminum housing, is designed to operate in a maritime environment, with shock resistance to 10 Gs, vibration to 1 G, operation from -20 to +50 degrees Celsius, storage from 40 to +70 degrees Celsius, waterproof, and resistant to 95% humidity and salty mist conditions

# 4
# MULTI SHIP APPLICATIONS

## 4.1 INTRODUCTION

Among the developments of PEPA technology currently being considered, evaluated, and/or installed by U.S. pilot associations (including those of Tampa, New Orleans, LA/Long Beach, Houston, and San Francisco) is the use of a wireless digital communication link to tie together individual pilot carry-aboard units. In such a system, the information provided by individual units is transmitted at frequent intervals (as often as once per second) to the other units in the system, providing each pilot with voiceless information on each ship in the system as well as his own. Such systems are variously refered to by different names and achronyms, among them "Silent VTS", "PIMS - Port Information and Management System", "ETS - Electronic Traffic System", and "AIS - Automated Information System". There are a number of different communications technologies being considered and/or evaluated by U.S. pilot associations to install such systems - each with their own advantages and disadvantages - and a number of issues surrounding the implementation of these systems. Opinions vary widely among pilots regarding the utility, application, reliability, and cost effectiveness of these systems. More than in any other area of PEPA development, this area of multi-ship systems and the communication links they employ is very much in its infancy. Complicating the picture are a number of factors, including the fast pace of the telecommunications industry's development of wireless digital comunications technology and the corresponding application innovations likely to occur in the future. While a comprehensive discussion of communications technology and AIS issues is outside the scope of this report, some the current technologies actually being considered by specific U.S. pilot associations is offered here. (Note: The Houston Electronic Navigation System (HETS), discussed in Section 3.2, features multi-ship capability.)

One multi-ship system and wireless communications link currently being evaluated (San Francisco - Port Operational Information for Safety and Efficiency "POISE" Demonstration, see Section 4.2 to follow) involves the use of an established local area network using wireless modems communicating to landlines and a dedicated internet web server which gathers and distributes real time navigation, traffic, and related data. Some advantages of this system as envisioned include: a relatively low cost of operation, the use of a pre-existent equipment and commercial services already available through which to broadcast and share data - shore based transceivers connected to landlines and the internet (i.e., minimal upfront equipment costs) the ability to process and offer a large amount of navigation and port information, and very small and light radio/modem equipment for the pilot to carry. Among the disadvantages are: the lack of security of the data flow, performance dependent on commercial internet service providers and location within wireless coverage area, and as yet unproven reliability. Update rates, data interchange content, and communications capacities are among some of the areas currently being evaluated in the POISE proof-of -concept demonstration.

Supporting a multi ship system called the Port Information Communications System (PICOMS), is a communications company with a successful background in aviation communication systems, ARINC (see Section 4.3 to follow). ARINC is presently working to install such a multi ship communications system in the port of Los Angeles/Long Beach. ARINC takes a systems integration approach tailoring a communication solution for each particular port. In supporting the idea that many users in addition to ship pilots will benefit from a port communications network, ARINC offers a system solution with enough bandwidth to accommodate a wide range of applications. ARINC supports a system which includes a wired Local Area Network (LAN) portion ashore with an information "gateway" concept, and a wireless LAN portion on the water utilizing spread spectrum and telcom phone line data links. The onshore and offshore portions are connected via a Ethernet physical medium and Internet TCP/IP protocols for data transmission. The ARINC solution offers a comprehensive system with large communications capacity for a wide range of port users.

Another AIS concept being considered by certain U.S. piloting associations and already in place in various Canadain locations, Valdez, and Puget Sound, is offered by Ross Engineering (see Section 4.4 to follow). In this system, vessels would have a transponder unit which the pilot would carry aboard (or be fixed on the vessel). A base station, with an operator and AIS central computer, would initiate and support communication between the transceivers within range of a transmission tower. The communications utilize Digital Selective Calling (DSC) broadcast mode as the medium of communication.. This system has the capability of transmitting the positional information of all the vessels equiped with a transponder as well as navigational support and distress information.

Another AIS technology being considered by U.S. pilot associations and currently being evaluated by the British Columbia Coast Pilots is Meteor Communications Corporation's VHF-Extended Line of Sight (ELOS) based AIS (see Section 4.5 to follow). This system utilizes a MCC RF modem as the VHF transceiver which can function as a transponder, a base station, or a repeater staion. The communications network operates line of sight on a single frequency in the low VHF band using groundwave. The network combines a carrier sense, multiple access mode with time division multiple access. to realize a reported 90% channel utilization rate. The system is highly configurable for different applications and can operate in various modes, including ship to ship, silent VTS mode.

## 4.2 SAN FRANCISCO BAY AREA DEMONSTRATION AND ASSESSMENT OF THE PORT OPERATIONAL INFORMATION FOR SAFETY AND EFFICIENCY (POISE)

The following description of the POISE concept (Section 4.2) has been provided by David J. Petraszewski of the U.S. Coast Guard Research and Development Center, Groton, CT.

*What is the San Francisco POISE demonstration?*

This demonstration is an experimental service designed to deliver navigation information to anyone with Internet access. The intention is to provide marine navigation information about the San Francisco Bay area concerning:

- vessel locations, movements, intentions, characteristics, and status,
- restricted and one way traffic areas,
- water and weather conditions,
- railroad and automobile bridge status,
- marine advisories, and
- temporary changes to aids to navigation, port facilities and schedules.

The information is action oriented and provided to support navigation decisions. Experimental software, designed to view this information using a PC with Windows 95 or NT, is being provided free of charge. It will be available from the POISE web site. This software presents the information against a chart background. This experiment is being conducted to better understand the nature of, and benefits derived from, the timely distribution of navigation sensitive information.

BACKGROUND.

The United States Coast Guard Research and Development Center (USCG R&DC) is conducting tests in the area of San Francisco Bay as part of a research effort designed to assess the value of the POISE concept, and the technology and standards needed to support it. This research is being conducted using existing commercial and government services in the San Francisco Bay area.

The goal of POISE research is to identify available real time information that can be provided to the marine public for the purpose of improving the operational performance of the waterway and to develop the technologies needed to support timely access to the information. POISE research is based on the premise that improving the availability of navigation information can: improve safety, reduce the costs of marine commerce, increase the capacity of existing shipping lanes, improve protection of the environment and increase the enjoyment realized by recreational boaters. In addition to identifying available data, the POISE research will also study and recommend alternative methods for distributing the data.

Special purpose navigation information is already improving the safety and efficiency of the nation's waterways. Examples of such services include the existing USCG NAVTEX and DGPS (Differential Global Positioning System) services. NAVTEX provides urgent marine safety information needed for safe voyage planning. The DGPS service provides the marine community with the real time corrections to the DOD GPS signals that are needed to significantly improve knowledge of vessel location, speed over ground, and course over ground. The DGPS service significantly reduces the navigation uncertainty that has historically been the cause of numerous vessel groundings. POISE research builds upon the experiences gained and benefits realized from services such as NAVTEX and DGPS.

The San Francisco Bay area POISE demonstration is being implemented by development and deployment of a proof-of-concept system that will electronically gather and distribute data about that waterway. Participants in this research will be given direct access to the information even as the capabilities of the proof-of-concept system are being developed. In order to get an operational assessment of the POISE concept's value, this research effort includes working directly with the professional mariners who routinely navigate the Bay area on a daily basis.

*How is POISE information delivered?*

The information gathered by the experimental POISE service is maintained and managed by an internet web server located at the R&DC. This server gathers and distributes real time information using the Internet. Any user with internet service will be able to access the information maintained by the server. In order to experience reasonable performance, the POISE user's equipment will need to be a high-end Pentium processor. For example, 166 MHz. Pentium notebook computers are presently being used as the portable user equipment in San Francisco.

The software developed to view POISE data is designed using a combination of established and draft standards and contains several major elements. The graphic presentation of chart and vessel information is designed to allow the users to experiment with the presentation of the information. The symbol and chart conventions comply with a variety of national and international conventions (IHO S-52 colors and symbols - version 2.0 and edition 3.0, unofficial IHO S-57 vector chart data, NOAAIBSB raster charts, and experimental symbols being developed by IALA for AIS, to list a few). This software is government owned and is being provided without charge. Some of the major features of this software are:

- A display with both chart and POISE server provided real time information,
- User selection of either NOAA Hybrid vector, proprietary vector, or NOAA/BSB raster charts,
- A "navigation window" containing "own ship" information,
- A master communications window with direct access to web sites with marine information,
- Automatic reporting of DGPS derived position, speed, and course to the POISE Server,
- A data base used to identify symbols and obtain additional chart object information, and
- Support for all Windows 95 local and network capabilities such as web browsers and E-mail.

The shipboard installation of the POISE user equipment and software should include differential GPS equipment. The DGPS equipment provides the "own ship" information shown on the POISE display. Information from the DGPS equipment is also passed to the POISE server over the internet.

The POISE server also monitors the performance of the communications link with each user. This feature will be used to monitor the age of information distributed to each user. The POISE performance experienced by each user will be affected by their internet service provider and their location within the coverage area of wireless internet service providers. The server also acts as the distribution point for those POISE users needing the latest revision of the POISE users' software. Both the POISE user equipment software and the POISE server software will continue to evolve in response to professional mariner needs identified throughout the course of this demonstration.

*Where is the POISE demonstration going next?*

Development of the equipment and software has reached the point where some subsystems are being deployed to help in overall system development and testing. Equipment installed aboard the San Francisco Bar Pilots "Golden Gate" pilot boat is being used to evaluate wireless internet coverage in the Bay area. Efforts are underway to obtain live vessel track data from the data base maintained by the USCG on Yerba Buena island (YBI). Inclusion of the YBI data is the next major demonstration milestone.

## 4.3 ARINC

The following contribution (Section 4.3) by James Maida, Technical and Product Development Consultant to ARINC, describes ARINC's Port Information Communication Systme (PICOMS).

### INDUSTRY OVERVIEW

One of the major statistical data points used to determine a country's developed status relative to the rest of the world is to correlate the number of telephones available (per 100 people) to the total population. This not only tells plenty about a country's current state of evolution, but more importantly, how it can successfully compete in the future. In fact, the resultant growth in telecommunications technologies, and more recently data communications, has been a fueling force in the global expansion of today's economies. Buying and selling, currency exchange and other financial transactions are made possible mainly because of the near instantaneous availability of data and ability to have 7 day/24 hour access to people around the world. This also directly correlates to the expansion and development of micro-economies more associated with specific marketplaces such as the maritime industry.

As we approach the 21st century, the maritime industry should prepare itself for a communication explosion. Similar to the introduction of voice communications, and even when shipboard radar first became available, the introduction of newer data communications technologies is about to rush in a new era within the maritime industry, one of endless possibilities, as well as challenges. The constituents in this industry are about to embark on a voyage they probably could not have imagined just a decade ago. Providing new capabilities they may not yet fully comprehend, but will be necessary if they are to successfully compete in a globalized economy in the future.

The question is not is the population ready; of course it isn't. But rather, is it willing to have the desire, forethought, and vision to embrace the technology and realize its full potential? Unfortunately, the state of the industry today appears full of confusion and uncertainty due to a non-consensus among various user groups. This paper will attempt to shed some light on newer communications technologies that can lead to the development of port information communications systems which have the potential of meeting all of their individual needs, as well as bring into perspective the need for industry users to rally around and embrace this technology.

### USER COMMUNITY

Before discussing a port information communications system, an important question must be asked: Who are and who will be the users and eventual benefactors of this new communications explosion? Unfortunately, today potential beneficiaries themselves don't even realize who they are. Not only will it take time before they realize it, but they will emerge at different times and at different rates. Adoption of new technology does not happen overnight, but it happens over a short enough of a period that we have difficulty imagining what it would be like without this technology. For example, it is almost unthinkable to believe how we could have ever functioned without a fax machine, which has come about only in the last decade or so. But like any new technology, there are early adopters who will lead the way and pioneer the trail. In the case of the ports, that distinction falls initially upon the port's pilots and, subsequently, on other port entities, such as the local port authorities, marine exchanges, marine safety offices (operated by the US Coast Guard in this country), and Vessel Traffic Centers (if they exist), etc.

Along with the pilots, these entities become responsible for the introduction and implementation of the technology. Also in concert with the pilots, but not necessarily in exact synchronization, will be ship owners themselves. Then at a later point in time, when the technology is perceived to be mature by the user community (although it may in fact have been mature from a pure technology standpoint for some time), the other general population of users emerge and will jump on the proverbial bandwagon. What all ship-related businesses and associations have in common is that the efficient handling and turn around of each vessel can greatly impact their competitiveness, and in turn their economic performance. If a port information communications system was implemented that could have a direct economic influence on their operations, there is no doubt they would be interested in becoming a user of this system.

In a perfect world, where everyone could adopt the technology at the same time, things would be much simpler. Unfortunately in a not-so-perfect real world, the idea of users with differing interests entering the user arena at various times presents some challenges. Mainly, if one implements such a system, how does one ensure that varying needs will be met, not only today but in the future as well. Even with early adopters, such as pilots, there is a mixed group consisting of pilots who are mainly navigators (i.e., Chesapeake or Delaware Bay), some that are docking pilots or docking masters, and some that are both. Although they have general requirements that are common among the profession, each organization and location has specific and unique needs that will impact the implementation of any communications system within their geographical region.

## COMMUNICATIONS CONSIDERATIONS

The first consideration in selecting the proper communications system is the determination of the various potential users of any port information system. This will define its real purpose. Is it for vessel position reporting only, or are other economical factors involved? Although this sounds simple enough, it is only the beginning of a series of hard complex issues and questions that need to be addressed before one can select the appropriate communications system to meet the potential user's specific needs. Some additional considerations one should take into account are: what type and amount of data will be required; how and when would the users likely want access to the data; and whether any users want or need one-way or two-way communications.

For example, the US Coast Guard who's primary concern is with safety has data requirements that may be limited to position reporting. At one point in time this was only reports from traffic vessels to a central Vessel Traffic System (VTS) or Vessel Traffic Information System (VTIS) center. But more recently they have added requirements to broadcast traffic information out to the vessels and an inter-ship communications capability, which has collectively become known as "Silent VTS." The interest of other users, such as the pilots, local port authority, ship owners, or multi-modal carriers, may be toward having a direct communications link to the vessel for other operational reasons. In addition, other relevant data, such as local weather forecasts, and tide and current data, etc., that can have an impact on both safety and economical operations may be desired. Likewise, in the absence of a Coast Guard Radio Beacon or for redundancy purposes, does a port wish to transmit it's own local differential GPS (dGPS) or even higher precision kinematic GPS (kGPS) satellite corrections, further adding to the data link bandwidth requirements? Therefore, individual ports and each user within the port have different requirements of the system. But, in order to implement and maximize the effectiveness of any communications system, both near term as well as future requirements need to be considered. This foresight appears to be lacking from any current industry discussions. Such issues become an even greater challenge when one considers that no current standards exist and that this is an international issue eventually requiring international cooperation and coordination.

Other issues making the system selection difficult is that the VHF spectrum is very limited and there is no maritime UHF spectrum available. In addition, the inter-ship communications method in and of itself is an interesting challenge, because it can be performed either through a direct ship-to-ship link or sent through a shore-based station that functions as the intermediary. The end result, however, is that the communications system selection is not a trivial one, and the entire set of user requirements need to be addressed and factored into the overall architecture. From a vendor or solution provider standpoint, this does not make things any easier because it makes system development and sales effort much more difficult.

## COMMUNICATIONS SYSTEMS OVERVIEW

Although there is some limited HF communication systems (i.e. over-the-ocean air traffic control), from a historical communications standpoint, there were generally two types of communications approaches one would look at, namely VHF and UHF,). There are several voice and data subsets within these two groups, such as trunked radio, specialized mobile radio, paging, and cellular, just to name a few. But the discussions will be limited to the overall category since the issues are focused around the spectrum utilization rather than the specific communications subset. Recent advancements in cellular technology has brought about the implementation of cellular digital packet data (CDPD) as a viable land-based data communications medium. The author is not aware that the FCC has authorized, or if any cellular provider is planning on extending this coverage over any bodies of water. The other issues are that CDPD is still a relatively low bandwidth application and is only available from cellular providers with accompanying access and message costs.

To bring it into perspective, lets first look historically how RF radios operate. For example, for a standard VHF radio operating at a frequency band from 175 to 185 Mhz would give the user a total theoretical spectrum bandwidth of 10 Mhz. However, each user operates only on one channel within the spectrum, so the users actual usable bandwidth is much less and is limited to something less than the channel bandwidth. Historically, the channel bandwidth used to be 25 Khz. But in most environments it has currently been reduced in half to 12.5 Khz, and in some applications (i.e. airborne) it has been reduced even further to a third, or 8.33 Khz. This means that the entire signal is contained within the 25, 12.5 or 8.33 Khz bandwidth. For the 25 Khz example, the 10 Mhz spectrum theoretically would allow for approximately 400 channels (10 Mhz or 10,000 Khz / 25 Khz). But because of guard bands, in reality the actual number of channels is less. Regardless, this doesn't affect the bandwidth issue at hand.

Because of the overcrowding in the VHF band, the trend has been for reducing the channel bandwidth to accommodate more channels over the same spectrum. With the advent of the computer and the need to send more and more data, the applications trend is toward more bandwidth not less, making the VHF and UHF bands less likely to satisfy current and long term needs of most computer oriented wireless data communications systems. Over the past several years, there has been an effort to extend the life of these spectrums, mostly in the digital cellular and more recent Personal Communications Systems (PCS) markets. As a result, we continually hear about other technologies, such as Time Division Multiple Access (TDMA) and Code Division Multiple Access (CDMA), which at first appear to be replacement for older VHF and UHF systems. On the contrary, they are actually digital communications schemes that can be implemented at any frequency, including those at VHF and UHF, and have emerged as leading contenders in the race to provide the next generation voice and data communications systems.

CDMA has been touted as the technique that makes more efficient use of the total spectrum. Unfortunately it is no panacea, because it's inherently more complex and presents other implementation challenges that question it's dominance over TDMA. Since these systems are still coming on line, only time will determine which is the more economically viable approach.

TDMA is the process of "time-slicing", thus the term time division, whereby each second of time is sliced into smaller time intervals for multiple user access. Each time interval is assigned a specific slot which is in turn assigned to one user of the system. For example, let's say you wanted to transmit data to all users (e.g. 10) once every second. Theoretically, you would divide the total one second interval into 10 user slots, so that each user had .10 sec to transmit their data. So at the end of the one second interval you would have received data from all 10 users and at the start of the next one second interval the process would repeat. In the real world, because of communications overhead and other factors, each user would actually get something less than the full .10 seconds allocated for their respective time slots.

CDMA on the other hand is quite different. Each user is essentially assigned a unique "code," that allows each user to transmit during the same and entire one second interval. Because each code is different for each user, it allows each user to transmit simultaneously or have multiple access, minimizing (recall this is not a totally perfect world so it can't be totally eliminated) the chances of interference between any users. In effect, the one second interval was divided not by time, but by code, and thus the term code division. As you can see, instead of each of 10 users having only .10 seconds to transmit their data, they have the entire one second at their disposal. Once again, because of communications overhead and other factors they actually have slightly less than the full one second interval. When comparing the two schemes, one can clearly see why within the same frequency band CDMA has the potential of providing a much higher bandwidth than TDMA

There is currently available certain TDMA schemes that have demonstrated applicability to the maritime market. But once again, the users must ask themselves what are the expected current and future requirements. To simplify things, bandwidth can be considered a function of three things: 1) how much data can one send, 2) how much time does one have to send it, and 3) how often, or at what rate (i.e., at once per second) does one get to send it. If I have a lot of data, have a long time to send it, and can send it very frequently, then the bandwidth is very high. Likewise, if one has only a short time to transmit data, this limits one to a small amount of data that can be sent, and it can be sent very infrequently (i.e. once per 10 seconds), then the bandwidth is considered very low. Keep in mind this is relative bandwidth, because it is frequency dependent. For any given communications scheme, the higher the frequency, the higher the bandwidth. In other words, a TDMA transmission at UHF would have a higher bandwidth than the same TDMA transmission at VHF.

Let's take another look at the above TDMA example where we have 10 users (i.e., vessels) each having .10 seconds to transmit their data once every second (the update rate). In the first instance let's assume each user wants to increase its data by two, thereby requiring .20 seconds to transmit all of their data. If I still wanted to communicate with all 10 users, I would have to reduce my interval to once every two seconds. If this was not satisfactory and I wanted to maintain the one second update rate, for a .20 second transmit time per user, I would have to reduce the number of users that could transmit in that interval to 5. Quickly one begins to see how as requirements may change overtime, either through increases in the number of users (not necessarily limited to vessels, since this could be shore-based users accessing the network) or in the amount of data one needs to pass through the network, the TDMA approach, especially at VHF frequencies has the potential of not providing enough bandwidth. In the CDMA approach, since I'm not dividing the time among users, theoretically, all one does is add more codes as more users are added. Then existing user's bandwidth is not sacrificed for each new user added to the network. Although this is another reason why CDMA is inherently more efficient, there's a higher implementation risk today with CDMA because it's somewhat less mature than TDMA.

Recalling the previous discussions relative to user requirements one might argue, and may be perfectly correct in assuming, that for low bandwidth usage such as position reports, which do not occur too frequently or for a limited number of participants, TDMA may well be a sufficient solution. The question each port must once again ask, is this all I ever really want to do? When the requirements are analyzed with respect to the user community as a whole, one would have to begin to question whether the inherent low bandwidth of these communications methods would suffice, not only today but well into the future. When one takes the time and money to install a communications infrastructure, future requirements should be part of the selection criteria or one could find themselves reaching their capacity limits in a very short time.

## COMMUNICATIONS SYSTEMS COMPARISON

In real estate or retail, everyone has heard that the industry cry is "location, location, location." In data networks, the synonymous cry becomes "bandwidth, bandwidth, bandwidth." So, if standard VHF and UHF have low bandwidth, TDMA provides only a somewhat higher bandwidth (by making more effective use of the spectrum), and CDMA is yet higher still (but more risky), how can one propose to solve their wireless data communications needs. Although at first glance it may appear hopeless, all is not lost. Borne out of the military environment, and after technology transfer to the commercial world, recent advances in "spread spectrum" technology have led to the development of a whole new generation of wireless voice and data communications products and capabilities. ARINC, as provider of PilotMate™ , a dGPS/kGPS-based vessel navigation, docking and tracking unit for both pilot carry aboard and permanent installation, has successfully demonstrated spread spectrum technology at the Port of Long Beach.

Spread spectrum derives it's name from the effect of "spreading" the signal transmission over a band of frequencies or in some cases the entire frequency spectrum. Instead of transmitting always at a single set frequency, each and every frequency within the band is used by the radio to transmit its data. Spread spectrum technology is similar to and has it's roots in the same military areas as CDMA, and comes in two forms, direct sequencing and frequency hopping. Without getting too technical, in essence, the first approach assigns sequencing codes and the second approach hops (or changes) frequencies according to a preset pattern. In both cases, each user has access to the entire band or spectrum and, therefore, inherently has higher bandwidth.

In addition, besides the two types of spread spectrum radios available, there are essentially two major frequency bands allocated by the FCC, 900 Mhz and 2400 Mhz (2.4 Ghz). There is also another frequency band, in the 5200 to 5700 Mhz range that also is emerging. Because it is so new it isn't considered at this time, but shows promise for potential future implementations. Therefore, our discussions will be limited to the 900 Mhz and 2.4 Ghz spread spectrum radios. The Table-1 below lists the advantages and disadvantages of the various communications frequencies and methods available for implementing a port-wide data communications system.

| Frequency Range | Method | Advantages | Disadvantages | Comments |
|---|---|---|---|---|
| VHF | Std | 1. Longest range | 1. Lowest bandwidth<br>2. Little or no maritime frequencies<br>3. Requires FCC license<br>4. Difficult to perform ship-to-ship link | Apparently a single continental North America frequency license is available |
| UHF | Std | 1. Long range | 1. Only slightly higher bandwidth than VHF<br>2. No maritime frequencies<br>3. Requires FCC license<br>4. Difficult to implement ship-to-ship link<br>5. Upper part of band very crowded | Still line of sight, so this doesn't buy much |
| All | TDMA | 1. More bandwidth at a given frequency<br>2. Can use for VHF or UHF | 1. Time Synchronization required<br>2. Bandwidth limitations | Can be synched to GPS time |
| All | CDMA | 1. Even more bandwidth at a given frequency<br>2. Can use for VHF or UHF | 1. More complex than TDMA<br>2. No time synchronization required<br>3. Immature technology | Just coming on line with satellite and terrestrial voice communications links such as Iridium |
| 900 Mhz | SSR | 1. Very high bandwidth<br>2. No FCC license required<br>3. High immunity to interference | 1. Lower range requires multiple stations for coverage area<br>2. Crowded spectrum<br>3. Not acceptable in Europe | Technically still considered upper band of UHF |
| 2.4 Ghz | SSR | 1. Highest bandwidth<br>2. No FCC license required<br>3. Highest immunity to interference<br>4. Non-crowded spectrum<br>5. Internationally accepted | 1. Lowest range requires even more stations for given coverage area | Comparative cost wise to VHF/UHF |

**Table -1: Communications Frequencies and Methods Comparison Matrix**

One of the main problems in the selection of the "right" communications system, as previously mentioned, is the lack of any US or international standards established at this point in time. There is ongoing work, both within the RTCM and IMO arenas, that is attempting to address this issue. But, instead of industry driving their requirements and driving forward, having manufacturers respond by developing solutions accordingly, the reverse has taken place. Vendors have taken liberty in steering the standards efforts in what could be considered self-fulfilling directions, by force fitting the user needs into their equipment. The problem is: whose user needs are they even attempting to address? History has proven that once a standard is established it becomes hard to reestablish another perhaps newer and better standard, because it invariably requires backward compatibility with legacy systems. Therefore, it is of the utmost importance that care be taken in establishing the standard, since it will be something the user community will have to live with for potentially a very long time.

The over-riding reasons why a VHF communications method would be chosen for implementing any port information system is that its range from a single station could potentially provide enough geographical coverage to address the entire port's needs.

At first glance a single station supplying an entire area's coverage may seem like a positive thing. But, when one looks at the statistical nature of the data interchange, a single station would mean that 100% of the data traffic must "funnel" through this station. Therefore, 100% of the entire network bandwidth must rely on and be provided by this station. For redundancy purposes, a second station as a minimum should be implemented. Nevertheless, the requirement for each of these stations to handle the entire network bandwidth still exists and is one more reason why VHF is a limiting solution for providing a long term port information communications system.

Both TDMA and CDMA are methods or schemes for enhancing the efficiency of any type of communications system, whether that be VHF, UHF or L-Band (i.e., PCS or GSM1900). While both are viable alternatives to standard communications methods, they are still limited by the nature of the frequency of transmission. To-date these technologies have emerged initially in the digital voice communications field. Whilst these networks are primarily established to provide voice, industry competition has driven the need to also carry digital data over these networks. Unfortunately, although the data rates (9600 and 19,200 baud) may seem high when compared to standard VHF/UHF (2400 or 4800 baud), they are still quite low when compared to pure data communications networks, which can run 10 to 100 times higher.

Because of FCC regulations, spread spectrum technology operates in the unlicensed 900 Mhz and 2.4 Ghz industrial, scientific and medical (ISM) bands, which by definition means that no FCC licensing is required. So the equipment can be used in any port without worrying about obtaining separate FCC licenses for each and every port. Spread spectrum technologies provide the highest bandwidth but operate at much shorter distances. When functioning in a point-to-point mode (i.e., shore site to repeater), since the transmission path is very directional, some spread spectrum networks have been demonstrated to provide 50+ miles of coverage, comparable to VHF. When the mode of operation is switched to a point-to-multi-point configuration (i.e., shore site to multiple vessels), the coverage becomes omni-directional, resulting in a reduction in antenna gain and the range reduces to about 3 - 10 miles, depending upon manufacturers equipment and bandwidth requirements. Of the two frequency bands, the 2.4 Ghz band is emerging as the frequency of choice because of the overcrowded spectrum at 900 Mhz due to potential interference from cellular, paging and other wireless telephones operating in nearby spectrum.

## INDUSTRY ACTIVITIES

Due to the lack of much available spectrum, recent industry activities have suggested that VHF digital selective calling (DSC) could be a communications system solution. Because of the safety issues related to the use of DSC Channel-70, transition to an alternate frequency is required. There has been proposals and demonstrations of a hand-off scheme that allows initial contact to be made on Channel-70 and then reassignment made to an alternate channel for vessel traffic purposes, appearing to make this approach a viable solution for vessel traffic purposes.

When ship-to-ship communications made it's way onto the scene in 1997, subsequent proposals suggested that a TDMA broadcast scheme could be added to the DSC radios to solve this requirement. To date this has yet to be proven, so the jury is still out. In fact, there are also alternate VHF schemes at the lower end of the VHF frequency spectrum, which using vessels as repeaters, provide an effective method for extending the line of sight (LOS). They have actually demonstrated reaching vessels in excess of 100 miles away (not in radius because of the repeater effect). The difficulty with any VHF communications system, exacerbated because of the maritime application, is the ability to obtain a FCC frequency license for each port. Apparently, the extended LOS system has obtained a license to transmit at a specific frequency. The author is not familiar enough to know whether this was limited to an FCC license for use in the US or if it's international in scope.

Regardless, the bottom line issue is that VHF is generally a low bandwidth communications method. Although some pure TDMA schemes have also been proposed which should provide some enhancements in bandwidth, for previously mentioned reasons these schemes may still be quite limited. Recently, announcements have been made that suggest the industry would like to adopt the TDMA approach for an international standard. If one concludes that VHF is the only way to go, perhaps TDMA is the best method for maximizing the bandwidth available from VHF. The first question one must ask is which TDMA approach would be adopted. Like all communications schemes TDMA protocols can all vary and are not necessarily alike. Thus, any decision to select TDMA means that specific protocols must also be adopted in order to complete the definition of any such standard.

If range from a single station is the only requirement, then some form of VHF solution would be hard to beat. However, if range is only one of several other requirements, then there are other methods for achieving required coverage while also greatly increasing the network bandwidth. For example, at the other end of the scale is spread spectrum technology which provides the maximum in bandwidth potential, but at a cost of a reduction in range. Lack of range can be compensated for by implementation of multiple stations that provide overall port coverage through the use of a "cell-site" arrangement, which is currently being demonstrated at the Port of Long Beach and will be discussed more in a later section. An advantage associated with the use of multiple stations is that the total network bandwidth can be spread across each of the individual cells. Since statistically not all of the users will ever be in the same cell, for any given network bandwidth, you can either provide a higher per-user bandwidth or add additional users without compromising the total network bandwidth.

SPREAD SPECTRUM OVERVIEW

Similar to public cellular networks, spread spectrum stations are arranged in a cell configuration similar to that shown in **Figure-1**. Analogous to cellular, users are free to "roam" between and across various cells, because each cell performs hand-off to the next cell so that individual users can have a connection to the network regardless of where they are in the coverage area.

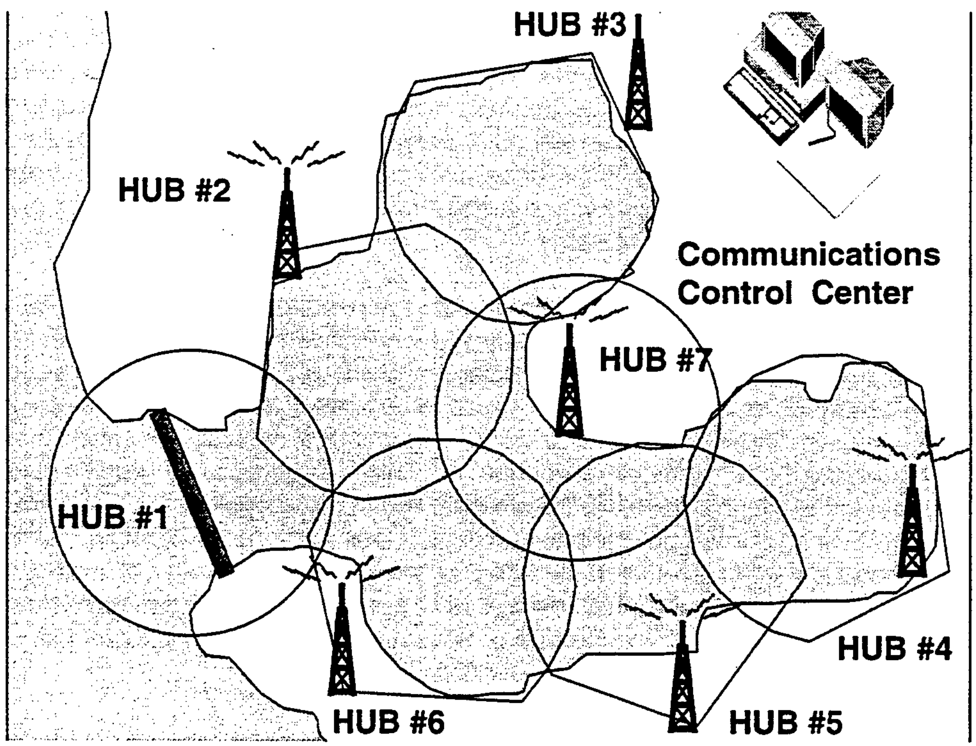



**Figure 1: Spread Spectrum Cellular Coverage Concept**

Most people are familiar with or have heard some of the more common data communications terms, such as local area network (LAN), Ethernet (IEEE-802.3), Token Ring (IEEE-802.5), bridges, routers and hubs. These terms which initially described "wired" networks, have now become synonymous with "wireless" networks as well. So to put spread spectrum into perspective, just think of it as a port-wide (over water) wireless extension to a shore-based (over land) wired network. What this essentially means is that just about everything you can do today with a LAN, such as email, internet access, and electronic invoicing, etc., can be accomplished over the equivalent wireless LAN.

Today, in some wireless network configurations one can have access to 1 - 2 Mbs (2,000,000 baud) of bandwidth and in the very near future near-Ethernet bandwidth of 10 Mbs (10,000,000 baud). Once again, real world conditions will limit this to something less than 10 Mbs, still fairly large when compared to today's VHF systems. One might ask: why would anyone ever need this amount of bandwidth? I contend that just like our computers, modems or office LANs of today, the larger the data pipe (equivalent to bandwidth), the faster we seem to fill it and demand a larger pipe. Once the port user community embraces this technology and the capabilities it will bring, they will surely drive the requirements to increase the bandwidth. This is a compelling reason why in going with the latest in Ethernet and wireless LAN technology, a port information system will surely provide the bandwidth growth necessary to meet the future demands of the varied users.

When first introduced, the initial wireless LANs conformed to either of the two major IEEE standards, 802.3 or 802.5. Similarly to wired LANs, equipment for one standard would not work with equipment from the other standard. To resolve this conflict, in June of 1997 the communications industry approved the newest wireless internet standard IEEE 802.11, which identifies a common protocol that will theoretically allow equipment from different vendors to interplay with each other, allowing a mixture of vendor equipment in any given wireless LAN architecture. In reality, it will take a few updates to the standard before this becomes easily accomplished. Since the marketplace is so lucrative, there is no doubt that the vendors whose interests are at stake will ensure that this happens, and sooner rather than later.

PICOMS ARCHITECTURE

A block diagram of the PICOMS Network architecture is shown in **Figure -2**. As can be seen from the figure, the overall network architecture consists of a wired LAN portion, located on-shore, and a "wireless" LAN portion that extends out over the water. The over-water transceivers are located on towers strategically located within the port to provide maximum coverage as required. The wireless LAN is treated just as though it was part of and directly connected to the wired LAN. All communications across both the wired and wireless LANs occur seamlessly because they utilize communication industry standard Ethernet physical medium and Internet TCP/IP protocols for data transmissions.

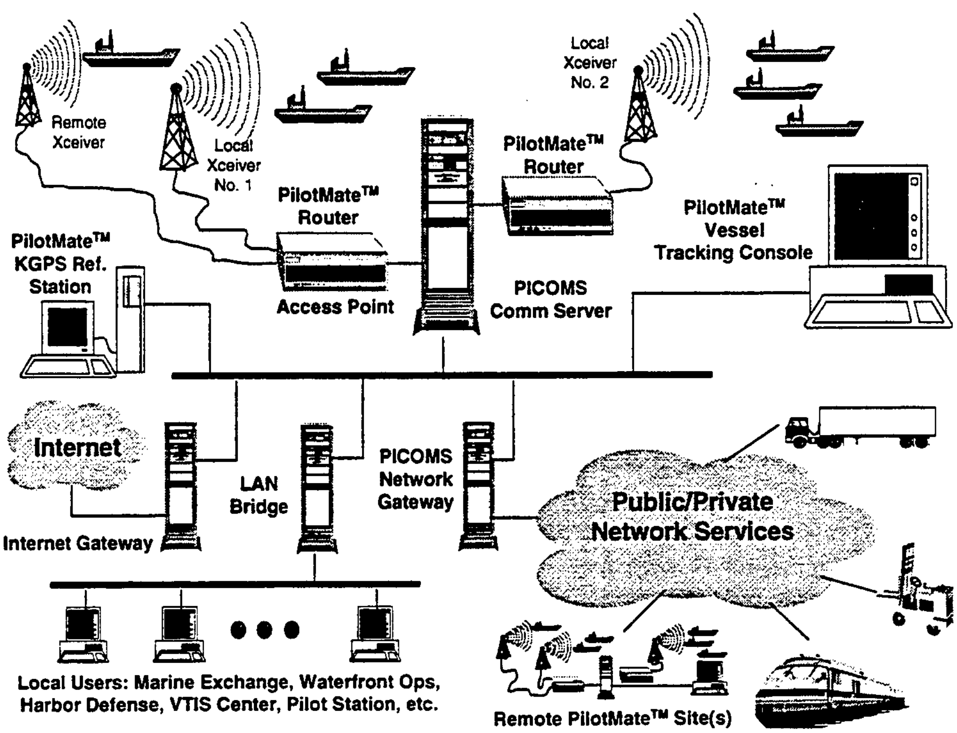



**Figure 2: PICOMS Network Architecture**

The wired LAN contains the main PICOMS Communications Server, and any other servers as required, such as file and print servers. On the shore side, since we are operating Ethernet we have the option of providing other servers or bridges, such as a LAN Bridge, PICOMS Network Gateway, and an Internet Gateway. These gateways allow port users of the PICOMS Network to have access to other data networks, both Ethernet and non-Ethernet based, as well as direct connection to the Internet. The PICOMS Network Gateway allows users of the network to gain access to other public or private networks, or it can be used to link to geographically separate PICOMS sites. With remote access capability, some or all of the port users have the ability to have remote terminals that can also access the network either through direct dial-up or an Internet connection provided through a local Internet Service Provider (ISP).

On the wireless side of the network, on-shore hubs are established to allow access between mobile terminals (located on vessels, ships, tugs, etc.) so they can communicate with users either on-shore or on other vessels. The Communications Server provides connectivity between the wired LAN and Wireless LAN through a device known as an Access Point. The number of hubs is mainly determined by the geographical coverage requirements of each port. Each hub functions in a "point-to-multi-point" configuration and acts as a central point or a router, where all communications to and from the mobile terminals occur and are routed to their proper destination. Communications between hubs and between any hub and the Communications Server's Access Point can occur either through telcom phone lines or linked via other spread spectrum "point-to-point" data links. The phone lines can either be leased lines or can be linked via an Internet connection, once again through a local ISP.

ARINC'S APPROACH

ARINC has a long standing reputation as a systems integrator, with more than 75 years in the communications industry as well as over 25 years of GPS expertise, dating back to when GPS was just a concept. ARINC is not an equipment manufacturer so it prides itself on providing the best and most cost effective solutions to their customers. Therefore, ARINC took a pure systems integration approach to the problem in an attempt to understand and determine user requirements, as opposed to trying to force fit a particular technology. Subsequently, ARINC feels that the spread spectrum technology holds the most promise and has the bandwidth today and for the foreseeable future to accommodate requirements of the various ports looking at implementing these types of systems. As a result, ARINC has chosen to develop their PilotMate™ units utilizing spread spectrum radios as their baseline data link. However, PilotMate™ is modularly designed with communications interface flexibility, allowing it to operate with various types of data radios in varying communications networks.

ARINC considers that currently the port information communications system requirements are still evolving, making requirements difficult to pin down. In order to take a systems integration approach they've decided that it was necessary to view the port and its users in a much more broader sense and select a communications solution to meet near term as well as long term communications requirements. This involved taking into account all of the various users of the system and providing enough bandwidth to accommodate a wide range of applications. In addition, user selection was not limited to only those with interested in navigation and/or tracking, which can be viewed as just a subset of the overall network utilization.

Once the pilots gain experience and the marine industry, in general, begins to adopt the navigation and tracking functions of the pilot carry aboard units, it's envisioned that these units will also eventually become part of permanent installation equipment. First and foremost from ARINC's perspective, is that these units are essentially communications terminals that bring land based communications capabilities out to the various ships (e.g., cargo vessels, tankers, tugs, barges, etc.). Once established, this communication link allows users on any vessel to communicate with any user on land, vise versa, between any other vessel in the network, and potentially between land-based users in the not too distant future. Secondly, that the navigation and tracking functions are viewed as software applications, representing only a few of many possibilities. As a result, the entire network architecture requires flexibility to support various new user requirements by accommodating future growth in applications.

ARINC RECOMMENDATIONS

As one can see, the process of selecting a port information communications system is both difficult and complex. One of the most important things to remember is that there are many and varied users, each with their own unique requirements. The size of a particular port infrastructure from an operational standpoint is a direct indication as to the type and quantity of potential users of the system. Their business interactions also providing an indication as to the scope required to implement an effective port-wide communications system. System selection is more complicated because of Coast Guard efforts to implement their next generation VTS/VTIS systems, which require a communications system that is primarily used for safety only.

The real key is that each port should take a broader look at its potential users and not limit themselves to just those interested in navigation or tracking information. In so doing, they will raise the level of awareness and need for greater bandwidth. Some ports may determine that their needs not only encompass but also surpass those of the Coast Guard. Does this mean that if their requirements significantly exceed the Coast Guard's, that a port might elect to implement its own separate port information communications system more in line with their needs? This is a distinct possibility, but once again, only time will tell.

The various ports, its users, and associated organizations, whether it be on the national or international level, need to get more heavily involved in steering the standards development. Knowing that the process takes time, they need to look for and expect a transitional period, whereby they can implement systems and associated networks now, with the full knowledge that there is a possibility that they will need to be updated at sometime in the future. What we don't need is paralysis by analysis. We need decisiveness on the part of the port decision makers, who need to look at it from an economical standpoint. If you wait for everything to be in place, including the standards, you could be waiting another 5+ years, all the time losing out on the benefits available from implementing a system today and falling further behind the learning curve.

What is required is a system that will give the appropriate capability required to solve the short term requirements, while also providing a path to the future. All the more reason for taking a look at the newer, more progressive spread spectrum communications solutions. If one looks at the success of the wired communications network industry and expansion of Ethernet and Internet technologies, one can envision a similar thing happening within the wireless network arena now that IEEE 802.11 has become an official standard. The maritime industry needs to look outside the box and embrace such newer technologies as wireless Ethernet and spread spectrum technologies, as well as possesses the vision required to move their port into the 21st century. This vision will be necessary in order to select the proper communications system that will carry their economies well into the future.

## 4.4 ROSS ENGINEERING AIS OPERATING REVIEW

The following contribution (Section 4.4) from Captain Larry Simpson of Ross Engineering, describes an overview of the Ross AIS System.

> The Automatic Identification System (AIS) is for use as a Navigation Safety System (NSS). This system can stand alone or may be interfaced with other monitoring devices such as radar and closed circuit TV. The older port control systems were really for "big brother," the U.S. Coast Guard, to watch the traffic. If they saw a potential problem, they would instruct the master or pilot on a course of action. Some professional mariners take exception to someone on shore giving instructions to the master or pilot who has responsibility. And really this was not a comfortable situation for the coast guard watch standees. Additionally, this provided a convenient means to apportion blame in the event of an accident.
>
> The new AIS is more of an information network. Its prime purpose is to provide professional mariners with a tool to anticipate problems and take action before they become an accident, a collision avoidance tool. You see, the AIS participants know who they are, what they are carrying, their width, draft, and various other information important in keeping vessels apart. Shore users may have access to this information for many reasons, such as scheduling, messaging and other company business. Communications with other vessels and even calls placed through the phone system can be achieved. And the coast guard can still watch what is happening, with the responsibility where it belongs, in the hands of the master or pilot in charge of the vessel's safe operation.
>
> *In general here is how the system operates today:*
>
> AIS is a system whereby mobile vessels are fitted with a " transponder" unit (automatic identification system shipboard equipment (AISSE) which may be fixed or Transportable. The AISSE units may be fixed, such as a DSC12500 or transportable, such as the DSC15000P pilot carry on.
>
> On a time schedule that is adjustable by the control station operator, the base station sends an electronic "all ships call" on Channel 70. This call can be a general or geographic call. In either case, only vessels fitted with AISSE units (not already logged in the system) will respond. The base station requests automatic information from the mobile (s) . The AIS computer will decide to enter the vessel into the system on a working channel or monitor the vessel on channel 70. Monitoring on channel 70 conforms to the current itu-r recommendations and is only done if the mobile does not have the capability to work on an AIS channel or if the AIS channel is inoperable.
>
> The AIS base will assign a group number, sequence number and channel to the mobile. The mobile will switch to the AIS channel. At the appropriate time the AIS base will inform the mobile of data pertaining to all other mobiles in the system. Upon entry into the system, all mobiles are given information pertaining to the new vessel(s) . As vessels move through locations near to or far from the transmitting tower, they can be automatically or manually shifted to or from low / high power.
>
> Up to 120 groups of up to 120 vessels in each group can be controlled by the AIS base. The AIS operator can move vessels from one group to another, or change the group timing interval.

The AIS computer keeps track of the timing for all groups and the timing of vessels tracked on Channel 70. The system assures that Channel 70 is operated in accordance with ITU-R recommendations with regard to channel loading. The AIS base at the appropriate time will initiate the sequence for vessels to report. As a vessel is reporting on the working duplex channel, the base is in repeater mode and is rebroadcasting location, course and speed as the vessel is sending. In this way all vessels on the working channel can receive the pertinent information of all other vessels in the control area including those who only can broadcast on channel 70 (channel 70 vessels can not receive working channel data). If the AISSE unit is interfaced with an ECDIS or computer with mapping, it will not only see its own position in the control area, but that of all other vessels. This allows the system to function as a collision avoidance tool .

Note: in areas where a duplex AIS working channel is not available, a simplex channel will work with each vessel receiving the data from other reporting vessels.

Messaging is accomplished ship to shore, ship to ship and shore to ship. An operator enters a free form text message, with its intended destination. The AIS computer recognizes a request to send from its own operator or a mobile and handles the transmission in appropriate packet sizes and times. All messages use the AIS tower. In this way if vessels are in the control area, they can receive and transmit messages to each other. With the AIS computer deciding on packet timing, there is a minimal time burden to the location reporting process.

The AIS control site is set up to allow authorized shore side users to view, but not control, any part or all of the control area. Authorized users can see exactly what the control operator is seeing with the "mirror" option or can zoom in or out on any area within the control zone. All information available about any selected vessel may be displayed on the screen.

From the ship board side the computer screen has available electronic mapping information and the icons: representing all participating traffic. The operators own information is available at all times, as well as information on any selected vessel including range and bearing data.

If route information has been loaded into the AISSE, the system will show the users position based on range line navigation and constant radius turns. With this, comes important steering data for the pilot or master such as a COI, distance to the right or left of center line (the vessel icon changes color based on right or left) and a countdown to up coming events such as a bridge or turn. The CDI distance is shown in feet or tenths of a meter.

If a DSC distress is received from any vessel an audible and visual alarm is made. If the vessel is not in the system, it is automatically logged in and tracked on Channel 70. An acknowledgment of the distress may be sent.vessels not reporting to the AIS will be shown in black if no position report is received after ten (10) reporting cycles. If position reports are resumed, the color returns to normal.

Vessels out of range or beyond the control defined area may be logged out. Their icon will be removed from the screen and their data from the data displays. Vessels logged out that remain in range or within the control defined area will be logged back in on the next automatic all ships call.

The AIS center software is written to be able to control, older versions of AISSE such as operates in Prince William Sound. Ross Engineering AISSE equipment is designed to operate on the most current ITU-R recommendations at the time of manufacture. These AISSE units are also designed to operate in areas where older control centers are located.

The AIS base station maintains a log of several weeks of operations depending on traffic loading and the operational needs of the traffic center. This log can be off loaded to other mediums and saved or replayed as needed. The system data can be made available for interface with other systems such as the Canadian Coast Guard INNAV (information on the maritime NAVigation) or other databases .

There are numerous options available to the AIS control station. Some stations are operated with their own DGPS reference station. This provides an all satellites in view update through the AIS working channel. "Ports"[8] data may be added where available. This gives periodic updates of wind, tide, current and other valuable information for display on the AISSE. Weather radar pictures may be added for periodic viewing on the AISSE . Precision docking is available enabling the pilot and push boat operators docking the vessel to guide the ship in for a "soft" arrival at the dock.

ADDING NEW FEATURES:

It is important to note that a real advantage of the Ross AIS system is that we follow the international standards of IMO and ITU-R. There is one major feature yet to be added, ship-ship reporting (broadcast) on the high seas. During the RTCM meeting held in April/May of 1997, Ross Norsworthy announced that we have designed a system called "a DSC broadcast mode utilizing structured TDMA techniques". The system is used for AIS and is implemented in accordance with ITU-R M.825-2, utilizing the "DSC gateway" approach to interface with other DSC equipment on ships and on shore stations and to automatically select working channel frequencies. Since the IMO has identified further needs 1.) to facilitate operations outside of the range of an authorized shore station, and 2.) for higher system capacity for high density waterways, this "DSC broadcast mode" was developed. Data information and messaging is DSC, per the ITU-R recommendations, and message content is per the AIS draft standard proposed by the IALA VTS.

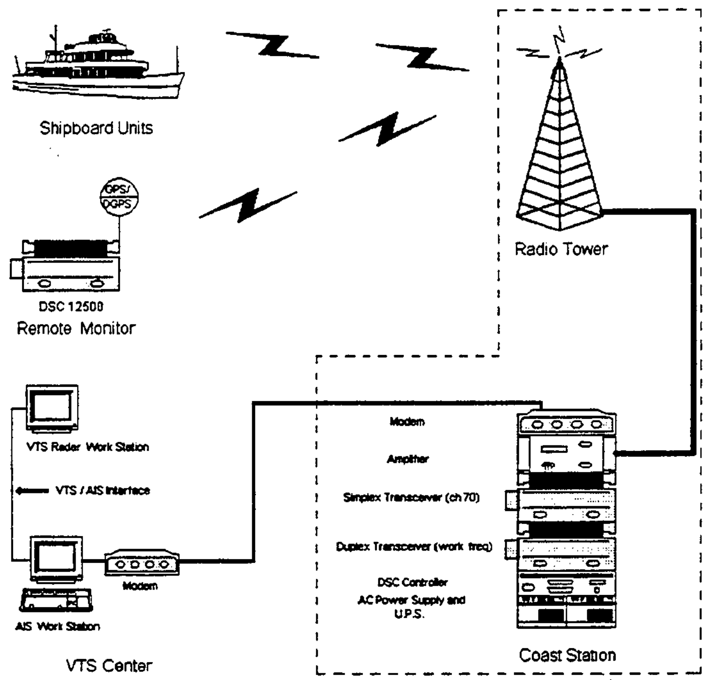
This system was many advantages such as not requiring global dedicated channels and is not burdened with " intellectual property rights" (any manufacturer can make equipment to use the technique without paying royalties). The system at 2400 information blocks per minute is fast enough to handle the busiest shipping areas in the world. In an area with a VTS, control switches to the VTS. This allows the VTS to get more reporting or less depending on area conditions.

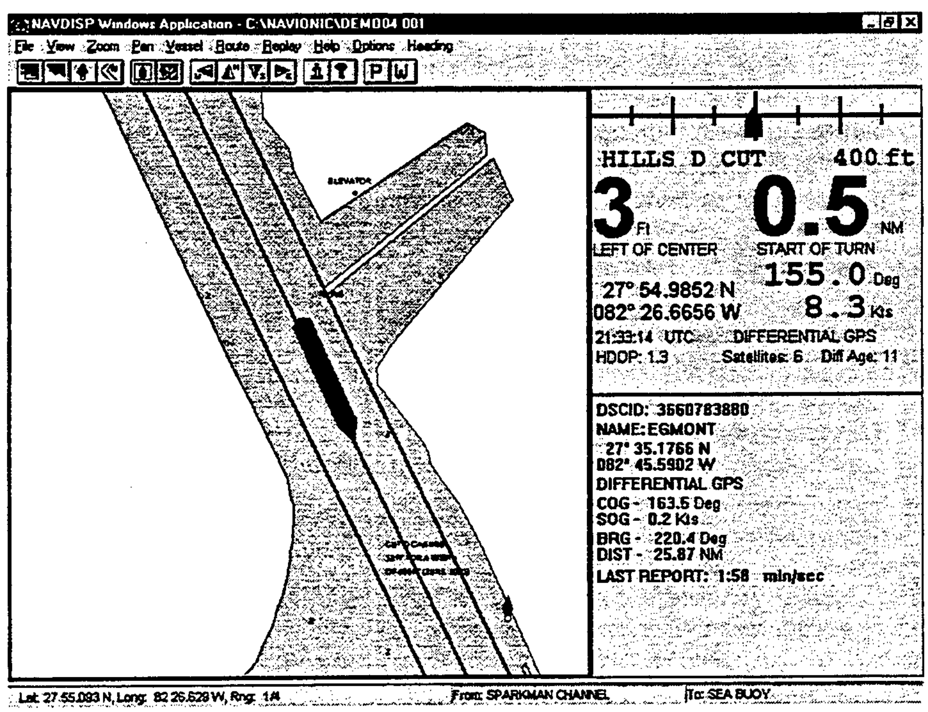
*Where are the systems installed?*

The first system was installed in Prince William Sound. There are five in Canada (four in the St. Lawrence and one on Vancouver Island). Two have been manufactured for Lockheed Martin for installation in Saudi Arabia and one for Morocco. In the U.S. there is one at the USCG

[8] The Physical Oceanographic Real-Time System (PORTS) is a program of the National Ocean Service that supports safe and cost-efficient navigation by providing ship masters and pilots with accurate real-time information required to avoid groundings and collisions. PORTS includes centralized data acquisition and dissemination systems that provide real-time water levels, currents, and other oceanographic and meteorological data from bays and harbors to the maritime user community in a variety of user friendly formats, including telephone voice response and Internet – Ed.

engineering C2CEN in Portsmouth Virginia and one just delivered to the VTS Puget Sound). Ross Engineering has an experimental system in Tampa Bay that is used for development with the USCG and the Tampa Bay pilots. There is a system installed with the LA lifeguards consisting of four base stations and a repeater site on Catalina Island, California. This system is used for tracking the vessels/vehicles, voice communications (clear and scramble), data transmission and PSTN interconnect for phone calls and connection with 800/900 and other communications systems.




*Simpson: Ross AIS System Description cont.*

## 4.5 APPLICATIONS OF VHF-ELOS TECHUOLOGY FOR AUTOMATED INFORMATION SYSTEMS (AIS) METEOR COMMUNICATION CORPORATION

The following description of Meteor Communication Corporation's Automated Information System (Section 4.5) was first presented the RTCM '97 Annual Assembly 27 April - 2 May, by MCC's president, Don Sytsma.


ABSTRACT

This paper provides an overview of using VHF extended line-of-sight (ELOS) technology for automatically tracking and displaying the position of vessels and providing secure two-way messaging from ship-to-ship and ship-to-shore.

Topics discussed are VHF-ELOS technology, system architecture, protocols, update rates and onboard electronic chart system (ECS) displays for collision avoidance, enhanced safety and protection ofthe environment.

Several operating systems in the US and Canada are described. Included in this discussion are vector based maps and charts, transponders, base stations and other system elements.

ELOS communication ranges may be seamlessly extended up to 1,000 miles, with the same transponder, using meteor burst technology.


INTRODUCTION

Meteor Communications Corporation (MCC) is the pioneer and world leader in the design, manufacture and deployment of turnkey meteor burst communication systems. Since 1975 the company has been successfUlly providing these wireless, packet switched networks to its customers throughout the world.

A meteor burst communication (MBC) network provides long range communications, up to 1,000 miles, by reflecting radio signals off the ionized trails left by micrometeors as they enter the earth's atmosphere. At the shorter ranges (50-100 miles) communication is by extended line-of-sight (ELOS) using groundwave. These two modes of operation are seamless and automatic within an MBC network.

The meteor burst channel is perhaps one of the most challenging mediums for ensuring reliable, error-fiee communications. The channel is intermittent, having a duration of about 250 msec, and is noisy with very low signal levels. The successful use of this channel, therefore, requires robust protocols, adaptive network software and very reliable hardware. This has been MCC's expertise and forte for the past twenty-two years.

Beginning in the early 1990s the company adapted this same robust technology to wide area networks using only groundwave. The first applications of these networks, called *FleetTrak*™, were for the efficient management and dispatch of a customer's fleet of mobile resources. Initially, *FleetTrak*™ provided automatic position reporting and two-way messaging for vehicles, aircraft and helicopters. Subsequently, these mobile resources included vessels of various kinds. Today, fully integrated AIS solutions have been developed for the maritime industry that embody DGPS, vector based charts and error-free communication from ship-to-ship and ship-to-shore.

VHF-ELOS TECHNOLOGY

The *FleetTrak*™ network operates line-of-sight on a single frequency in the low VHF band (40-50 MHZ) using groundwave. The range of communication by groundwave is primarily determined by diffraction around the curvature of the earth, atmospheric diffraction and tropospheric propagation. However, these ranges can be successfully extended through the use of robust protocols, sensitive receivers and short packetized messages. MCC's MBNET-200 protocols and network software has successfully accomplished this, providing error-free communication throughout the network at ranges from 50 to 100 miles.

The MCC-545A RF Modem is the VHF transceiver used in the network. It can be dynamically configured to operate in three distinct modes: as a transponder onboard a ship, as a base station or as a repeater station. As a base station, it is connected directly to a Vessel Traffic Center (VTC) via a leased telephone line. As a base station, it also maintains RF communications with all ships and repeaters operating within its own cell network.

When a direct connection to the VTC is not available at a particular base station site, the MCC545A is then configured to operate as a repeater station. As a repeater station, it routes all data to the nearest base station for subsequent delivery to the VTC. Multiple repeater links may be chained together for expansion of the network.

As a transponder onboard the vessel, the MCC-545A is free to roam throughout the network, automatically linking with the nearest repeater or base station. If there is no repeater or base station within range, it will automatically select the nearest vessel as its relay into a base or a repeater. When vessels are out of range of a repeater or base station, but within range of other vessels, they can communicate directly ship-to-ship.

NETWORK DESCRIPTION

The networking capability described above provides for a very efficient VHF-ELOS system operating on a single frequency. The network combines a carrier sense, multiple access (CSMA) mode along with time division multiple access (TDMA) for achieving a channel utilization greater than 90%.

It works like this. When a vessel wishes to communicate with the VTC, it sends a "poll request" to the nearest base station using the CSMA mode. The base station acknowledges this request by sending a "poll sequence" to the requesting vessel, assigning it a specific time slot during which to transmit its data. The vessel will then send its data in that particular time slot.

Since one base station may be in contact with hundreds of vessels at any one time, it organizes the responses from up to 10 ships on a single transmission burst (TDMA). The ten vessels will then report in sequence, in accordance with their assigned transmit slots. The base station acknowledges the data received from each of the ten vessels and then polls ten more vessels on the next burst transmission. If a vessel does not answer three consecutive polling intervals, it is dropped from that particular base stations' polling list. Likewise, if a vessel does not receive an acknowledgment to a poll request during the same time period, it will automatically select another base station and then becomes a participant in another group of ten vessels from the newly selected base station.

Using the above techniques, there is no contention and all position reports are delivered error free at a 90% channel utilization rate. With these efficiencies, sufficient channel time is still available for two-way messaging, vessel performance monitoring and various other data transfers.

A *FleetTrak*™ network can also operate independent of any base station or VTC. In this mode, all communications are ship-to-ship only. Each vessel's ECS will display its own position and the position of neighboring vessels. The community of vessels to be displayed can be selected based on range. In addition, the position update rates on vessels in close proximity to one another can be automatically and dynamically increased for collision avoidance.

A *FleetTrak*™ network can provide a "Silent VTS" enabling automatic VTS communication without operator interaction.

## OPERATIONAL SYSTEMS

MCC first demonstrated its maritime application of AIS capabilities in 1981 by tracking the Mobil Meridian super tanker between Valdeq Alaska and Ferndale, Washington using meteor burst. VHF-ELOS was used in Prince William Sound, Hinchenbrook Entrance and the Gulf of Alaska. MCC participated in various other vessel tracking projects with the US Navy in subsequent years. More recently, MCC's VHF-ELOS technology is being applied in the following networks:

1. British Columbia Resource Management System
2. Michigan Department of Natural Resources
3. PACMAR/AIS
4. International Tug-of-Opportunity System

A brief description of each network and its applicability to the marine industry is discussed below.

## BRITISH COLUMBIA RESOURCE MANAGEMENT SYSTEM (RMS)

The British Columbia Ministry of Forests (BC MOF) has responsibility for detecting and fighting over 3,000 wild fires in the 95 million hectares of mountainous forests in the province of British Columbia. During the height of the fire season, a fleet of airplanes, helicopters, and ground vehicles are manned by over 1,400 firefighters across a province 400 miles wide and 850 miles long. Voice radio channels on many frequencies were congested and situation maps were almost impossible to maintain. Resource usage was not very efficient and MOF required an automated Resource Management System (RMS). In order to track fast moving aircraft, a position update report every 30 seconds was required. There were no communication systems available that could carry such a traffic load over the vast expanses of the province. Satellite service was too infrequent and too expensive, and conventional packet radio systems were too limited in range.

In 1994, MOF contracted MCC to solve this problem by designing and deploying a VHF-ELOS AIS network to provide automatic position reports and two-way messaging for its mobile fire fighting resources. These resources included ground vehicles, bird dog aircraft, helicopters and tanker aircraft.

A pilot system using about thirty transponders was deployed in the summer of 1994. The pilot program was successful and the system was expanded to cover the entire province in 1995 with about 180 transponders. In 1996, the system was expanded to over 250 transponders and additional base stations were installed along the coastal areas for tracking marine traffic from Seattle's Puget Sound area to the Alaskan panhandle.

The BC MOF is continuing its work with the Canadian Coast Guard, the BC Ferry system and other maritime users in evaluating the VHF-ELOS network for marine AIS applications. GPS receivers and transponders have been installed and tested on several Coast Guard cutters, hovercraft, tugs and ferries. Position reports and two-way messaging are provided to the Coast Guard and Maritime Operations Centers through Intemet links from the MOF Computer Center. Both Centers can now accurately track vessels through narrow passages that were previously blind to other forms of communication.

The MOF network has proven to be an important test bed for evaluating AIS concepts and operational scenarios. The specific technologies tested and evaluated within this VHF-ELOS network that are directly applicable to marine industry AIS are as follows:

1. Moving map displays
2. Ship-to-ship communications
3. Ship-to-shore communications
4. Programmable update rates

MICHIGAN DEPARTMENT OF NATURAL RESOURCES

In 1996, the Michigan Department of Natural Resources (MDNR) began evaluating various technologies for automatic position reporting and two-way messaging for their law enforcement personnel. They reached the same conclusions as the BC MOF and, in fact, concluded that an emulation of the RMS network in British Columbia would meet all their requirements. MCC is currently under contract for the design and deployment of this AIS network that will place a transponder, GPS and mobile data terminal in 350 vehicles. Twenty base stations will provide complete coverage for the upper and lower peninsulas of Michigan, including portions of the adjoining Great Lakes region.

Position updates from all vehicles will be provided every thirty seconds. Additionally, the following functions and capabilities will also be incorporated into each vehicle:

1. Two-way messaging, including 120 preprogrammed canned messages
2. An in-vehicle emergency button
3. Automatic monitoring of ignition, light bar, siren overspeed and collision detector
4. Position updates as a function of speed
5. Marker drop
6. Key chain emergency button that will operate 1/4 mile from the vehicle

The above information is automatically routed from each vehicle to the Dispatch Control Center in Lansing, which serves as the host database and client/server to ten District Offices located throughout the state. Vehicle location and other data is displayed on MIRIS vector maps. Additional features are embedded DGPS and an interface connection to the MDNR email network throughout the state.

Although a terrestrial based AIS network, its features are directly applicable to maritime applications:

1. Automatic position reporting and two-way messaging
2. Ship-to-ship and ship-to-shore communications
3. Man overboard emergency transmissions and marker drop
4. Vessel performance monitoring
5. Update rates as a function of speed or proximity to other vessels

PACMAR/AIS

The PACMAR/AIS project is being implemented and managed by the Canadian Coast Guard and the British Columbia Chamber of Shipping. The objective of this project is to evaluate an AIS network using MCC transponders and the VHF-ELOS network in use by BC MOF. The participants in this evaluation are:

- British Columbia Chamber of Shipping
- British Columbia Coast Pilots Ltd
- Canadian Coast Guard
- British Columbia Ministry of Forests
- Meteor Communications Corporation

Six additional coastal base stations will be installed and integrated into the RMS network, providing continuous coverage along the entire Canadian coast from Vancouver to Prince Rupert. Transponders will be placed on a variety of vessels. Twenty vessels will only be equipped with transponder and GPS antennas to facilitate the test and evaluation of portable transponders to be taken onboard by the BC Pilots. The test and evaluation period will be for a minimum of six months and will have the following objectives:

- Evaluation of Technical Parameters
  - Coverage
  - Interference
  - Messaging and position reports
  - Ship-to-ship interoperability
  - Automatic handover between base stations
  - NMEA interfaces and data strings
- Operational Assessment
  - Viability of "carry-on" transponders
  - Identification capabilities within VTS operations
  - Tracking capability and accuracy of reports
  - Assessment of display requirements
  - Messaging capabilities

- Assessment of charting and information requirements

- Integration of AIS into VTS Operations
  - Ship-to-ship capability
  - Economics of an AIS system
  - MTR friendliness
  - AIS and non-AIS equipped ships within same VTS framework
  - IMO requirements for AIS transponders

Five portable transponders will be used during the test. Three of the transponders are designed to be used inside the bridge on the twenty vessels already equipped with transponder and GPS antennas. The other two transponders will be fully self-contained, including antennas, and will be placed on the deck, outside the bridge. A wireless link will be provided from the transponder to the Pilot's laptop computer inside the bridge.

The laptop computers will provide the Pilot's with two-way messaging and an electronic chart display. The vector chart will display identification, position, course and speed of own vessel and other vessels equipped with the same transponders.

The types of vessels that will be tracked in the PACMAR/AIS project are as follows:

- Tugs
- Cruise ships
- Super ferries
- Sea buses
- Deep draft vessels

INTERNATIONAL TUG-OF-OPPORTUNITY SYSTEM

The International Tug-of-Opportunity System (ITOS) is the result of the marine industry's efforts in the Pacific Northwest to improve the ability to respond to disabled oil tankers and the associated threats to the marine environment in the entrance areas to Washington State and Southern British Columbia (BC) waters, using the tugs which routinely transit these waters. A secondary focus of ITOS is improving the ability to respond in the waters of the Olympic Coast National Marine Sanctuary (OCNMS). This secondary focus was adopted by the marine industry in response to language included in the Alaska Power Administration Asset Sale and Terminal Act, Public Law 104-58, which was signed into law on 28 November 1995.

P.L. 104-58 directed the United States Coast Guard to:

> *...submit a plan to Congress on the most cost effective means of implementing an international private sector tug of opportunity system, including a coordinated system of communications, using existing towing vessels to provide timely emergency response to a vessel in distress transiting the waters within the boundaries of the Olympic Coast National Marine Sanctuary or the Strait ofJuan de Fuca.*

Since it is impossible to predict when and where vessels may become disabled while en route to or from Puget Sound or British Columbia ports, the most effective strategy to increase the likelihood that a tug would be available to reach a disabled vessel before that vessel drifts to a grounding is to capitalize on existing tugs which routinely transit through the areas which vessels transit. ITOS would enhance those existing tug resources through the addition of the organizational procedures and tug tracking capability necessary to raise efficiency of that historically proven "tug-of opportunity" process.

An ITOS coalition was formed in early 1996 and is represented by the following associations:

- American Waterways Operators
- Chamber of Shipping of British Columbia
- Council of Marine Carriers
- Puget Sound Steamship Operators Association Transportation Institute
- Western States Petroleum Association
- United States Coast Guard
- Canadian Coast Guard

The ITOS coalition investigated and reviewed all available technologies to meet the objectives of ITOS. MCC's *FleetTrak*™ technology was selected as the most cost effective and applicable technology. This decision was made by ITOS in February 1997. ITOS is now scheduled for full deployment by the third quarter of 1997. ITOS will be the largest maritime AIS network in the world.

Approximately 100 tugs, equipped with transponders and GPS/DGPS receivers, will be tracked using AIS technology. Information on each tug's status will be provided to the Marine Exchange of Puget Sound (MAREX) in Seattle, Washington. This information will include position, speed and course, availability, vessel capabilities (ship bollard pull), telephone contact numbers and/or radio frequencies and other pertinent information needed by MAREX and the Coast Guard to evaluate, identify and activate the closest, most appropriate tug(s) available. The update rate for all tugs within the ITOS network will be 300-600 reports per minute.

The AIS network infrastructure will consist of four base stations, each interconnected to the MCC Data Center via leased lines. The position information from the tugs is then routed to a client/server data base at the MAREX that also contains all the pertinent tug characteristics and capabilities. The MAREX base station will use a 21" color monitor to display tug positions on a vector ENC. The associated database will be available on pull down windows. The US and Canadian vessel traffic management centers in Seattle and Vancouver will be connected as clients to the MAREX server, providing this same information to augment their existing vessel management systems.

At this time, ITOS only requires identification, course, speed and position information along with access to the tug database. In the near future, this will be expanded to include two-way messaging from ship-to-ship or ship-to-shore. In addition, the fusion of radar data and AIS data on a single display, along with integration into a common Electronic Chart and Display Information System (ECDIS) platform will be a natural outgrowth on this project.

## CONCLUSION

VHF-ELOS technology has proven to be a cost effective and common sense approach for meeting the functional requirements of a fully integrated maritime AIS. VHF-ELOS operates over a very large geographical area using only one frequency and efficiently uses 90% of that channel capacity through a robust CSMA/TDMA protocol. Adaptive update rates, error-free communication and an open architecture for integration with ECS and ECDIS platforms are key features for the maritime user.

VHF-ELOS networks, using hundreds of transponders, have been successfully deployed and integrated into existing operational systems. It is a proven technology and it works.

# 5

# PILOT ASSOCIATION REPORTS

## 5.1 INTRODUCTION

While it is obvious that no two United States seaports are the same, the reality is that they are all quite different when looking at the piloting function. Each port is unique in its geography, economy, navigational challenges, hydrographics, currents, wind and weather, environmental sensitivity, ship traffic, etc. The piloting requirements and organizational infrastructure are correspondingly unique, presenting each local pilot association with its own set of navigational and operational challenges. The consideration and application of PEPA technology is therefore necessarily different for each port. What might be a useful and desired feature for one port might be of negligible value to another port. (e.g., What the Houston Pilots deem valuable in their consideration of PEPA technology in some respects is likely to be markedly different from what the Northeast Marine Pilots deem valuable.)

What follows are contributions from nine U.S. pilots describing aspects of the consideration, application, and evaluation of PEPA technology in their related ports. The contributions are based largely on experience with planning, acquiring equipment, and evaluating it as part of this research and development effort.

## 5.2 PILOTS ASSOCIATION OF BAY & RIVER DELAWARE

The following contribution by Captain Wayne E. Bailey and Captain Joseph F. Bradley (Ret.) details the PEPA experience of the Pilots Association of the Bay and River Delaware.

### OVERVIEW

The development of the portable pilot-carried navigation systems used by the pilot association of the Bay & River Delaware began in 1980, well before the implementation of GPS and DGPS service. Capt. Joseph F. Bradley of the Pilots' Association For The Bay And River Delaware, working with the USCG Research & Development Center and the Johns' Hopkins Applied Physics Laboratory, developed a portable Differential LORAN-C navigation system called PLAD. PLAD, short for Portable Loran Assist Device, was designed to be a self-contained, pilot-carried waypoint navigation system that required only a power source from the ship for its operation. This early system weighed about 30 pounds and eventually provided position accuracies of approximately 10 meters. The centerline intersections of the navigation channel, as measured by U.S. Coast Guard personnel, provided the navigation waypoints for PLAD. The navigation information provided by PLAD was: Cross Track Distance in feet, Speed Over The Ground in knots, Distance to the Next Waypoint, and Rate of Divergence from the Centerline in feet per second.

With the emergence of the Department of Defense GPS and U.S. Coast Guard Differential systems, Capt. Bradley shifted his work from the LORAN-C based system to one based on Differential GPS. Using equipment borrowed from the Magnavox Corporation, Capt. Bradley eventually proved the viability and improved accuracy achievable with a portable, DGPS-based system. Believing it was possible to further reduce the size, weight, and complexity of a portable system while adding to the system's capability, Capt. Bradley sought out other manufacturers in the GPS / DGPS industry and convinced Starlink Inc. of Austin Texas and Raytheon Service Company (RSC) to participate in his project.

Initially a Starlink GPS/DGPS receiver and antenna system was interfaced to the Magnavox unit. This was needed due to the lack of a screen display for the Starlink equipment. The interfacing work was performed by the RSC. Shortly after this was done, Starlink committed fully to the project and wrote a custom navigation program for use on a laptop computer. The navigation program was based on screens designed by Capt. Bradley, and provided much more navigation information to the pilot than either of the previous PLAD or Magnavox systems. The laptop computer was chosen because of its large display and easy adaptability to special programming. The computer was linked to Starlink's GPS/DGPS receiver and antenna system by a standard serial port connection. The new Starlink system weighed 13 pounds and required only a power source from the ship. Waypoints for this DGPS System were provided by the U.S. Army Corps of Engineers. Position accuracies of less than 2 meters were seen when using the Coast Guard's Differential Beacon Station at Cape Henlopen, Delaware.

In June 1994, the president of the Pilots' Association authorized the purchase of six Starlink portable DGPS systems and the formation of a temporary committee to evaluate the possible use by the Association's pilots. The six systems were received in August 1994. Most of the initial work of the DGPS Committee involved finding and recording problems with the software, suggesting improvements to the program, and refining the physical package that would ultimately be carried by pilots. In March 1995, the DGPS committee recommended that the Association proceed in procuring a Starlink Portable DGPS Navigation System for each of the Association's pilots. Due to the expense and logistics involved in training and equipping over 65 pilots with this new technology, it was decided to spread the procurement over an 18 month period. In October 1996, the last of the Association's pilots received his own system.

## THE PILOTS' ASSOCIATION DGPS COMMITTEE

Due to the large scale and complexity of the project, the DGPS Committee has been continued by the Pilots' Association. The committee is responsible for administering the project, recommending policy to the Association's officers, and evaluating future programming and plans for the system. The committee consists of five Active pilots, Capt. Joseph F. Bradley (Ret.) - Consultant, a representative of the RSC, and the Pilots' Association's Director of Operations.

## THE STARLINK PORTABLE DGPS NAVIGATION SYSTEM COMPONENTS

The Starlink PORTABLE DGI'S NAVIGATION SYSTEM is designed around the Starlink DNAV-212 receiver and Starlink's Mini Crossed Loop Antenna. Programming customized for the Delaware River and loaded on the hard drive of a TOSHIBA notebook computer completes the basic package.

The Starlink DNAV-212 combines a 12 channel Ashtech GPS receiver and the Starlink MRB-2A 2 channel automatic differential beacon receiver inside a single waterproof case. It provides real-time position, ground speed, course, and time measurement data. Raw satellite range and navigation data is updated every second. Position accuracy is continuously corrected with differential signals transmitted in RTCM standard code[9] which are received and processed by the differential beacon receiver. The beacon receiver uses two channels to provide automatic beacon selection. The primary channel tracks a signal while the secondary channel continuously scans the beacon frequency range. When a superior signal is detected, the primary channel automatically switches frequencies. The DNAV-212 provides multiple serial ports for computer interfacing and uses standard National Marine Electronics Association protocols.

The Starlink MBA-2 Mini Crossed Loop Antenna integrates both the GPS and Beacon antennas in a compact 1.5 lb. package. The antenna does not require a ground, mounts easily with a detachable antenna spring clamp, and connects to the receiver with a single coaxial cable. It has proven to be extremely rugged in all weather conditions.

The TOSHIBA Portege T3400CT laptop computer was chosen for use with the system because of its high relative quality, small size, and easily adaptable external power supply. The DGPS Committee specified that any laptop computer used be certified by Starlink for use with the system and have an Active Matrix (or monochrome) Display as opposed to a Dual Scan Display. The committee also required hard drive capacity sufficient to handle anticipated expansion of the system. All 72 systems purchased by the Pilots' Association were equipped with this computer. Replacements for computers damaged beyond repair have been other models from the TOSHIBA Portege series, as availability permits.

A 50' coaxial antenna cable, receiver to computer serial port connection cable, power supply with receiver adapter cable, plug adapters, extension cords, documentation manuals, and a soft sided computer carrying case complete the package.

[9] Radio Technical Commission for Maritime Services (RTCM) Special Committee No. 104, *RTCM Recommended Standards for Differential Navstar GPS Service, Version 2.1,* Washington, DC, January 1994.

SOFTWARE

Although the programming for the Delaware system consists of approximately 50 files, it can be thought of as being only two parts. The first part is the data sets for the Delaware and its tributaries. The second part is the navigation module called WHEELHOUSE.

The data sets are navigation waypoints, buoys and buoy locations, channel borders, lighthouses and fixed objects, and any other waterway specific items that the users need to use and display. The information for the data sets is obtained from official government sources such as the U.S. Army Corps of Engineers and the U.S. Coast Guard. Each data set is maintained by the RSC and encrypted to prevent alteration. It is essential that all DGPS systems in a waterway use the same data sets, especially for the waypoints. To ensure uniformity among various potential systems, the Mariners' Advisory Committee For The Bay & River Delaware has endorsed the publication of the Delaware Bay and River waypoint data set in the United States Coast Pilot and Light List. With their publication scheduled for late 1997, these waypoints will be the officially sanctioned waypoints to be used by all DGPS users on the Delaware.

The Starlink WHEELHOUSE module written for the navigation system is an adaptation of Starlink's DNAV utility program and the screen displays originally designed by Capt. Bradley. The program provides a series of function and route menus with all navigation information provided on one of two user selectable screens. The navigation information provided on one or both of the navigation screens is:

Cross Track Distance, Speed Over The Ground, Distance To The Next Waypoint, Bearing To The Next Waypoint, Course Over The Ground, Time To The Next Waypoint, Destination ETA, Satellite Information, Beacon Information, Dilution of Precision Information,[10] Waypoint ID#, Reach or range name, Latitude, Longitude, Local Time and Date.

A series of mode or warning flags is incorporated in the program to advise the user on the status of the navigation system. These flags are prominently placed on each operating screen and may be accompanied with an audible alert tone. Type 16 or RTCM messages from the Coast Guard are also displayed when received by the system.

The WHEELHOUSE program has undergone over twenty five revisions and periods of field testing since it was first issued in 1994. Early versions contained a limited set of features and were considered unstable by the committee pilots who tested them. After the first few revisions, stability and reliability of the program improved dramatically. Once the reliability of the program was proven, the DGPS Committee recommended the Association proceed with outfitting every pilot. The majority of subsequent revisions were made to add new features and enhancements as requested by the committee.

WHEELHOUSE is not waterway specific, and can use a properly formatted data set for any area. The current version of WHEELHOUSE has an extensive feature set with options that can be activated, or not, according to the users needs and wishes. Program features are reviewed by the DGPS committee, and accepted or rejected for inclusion in the final Association version of the software. Once a feature has been selected, it is activated on all of the Association's equipment. Individual pilots are not permitted to customize or activate features on their own. Like the data sets, WHEELHOUSE is encrypted to prevent user alterations.

[10] Dilution of Precision (DOP) is the sum effect of all combined error sources on accuracy when crossing two or more lines of position – Ed.

The software review process is now an ongoing function of the committee. Committee members receive new program versions every few months as they are released by Starlink. The criteria used by the DGPS Committee in evaluating changes or additions is:

1. Does the change / addition affect the reliability and stability of the program?
2. Does it slow down the updates of the program?
3. Does it integrate well with the other program features?
4. Is it necessary?
5. Is it easy to use? (Keep it Simple Stupid)
6. Is it a distraction to the user?
7. Is it time consuming to use?
8. Can the feature be safely used and understood by every member of the organization? This consideration is the most important and difficult standard to apply.

Additional features that the committee has currently selected for inclusion in the Association's version of WHEELHOUSE are:

Antenna Offset, allowing the operator to enter a correction for the distance the antenna is away from the center line of the vessel.
Record, Replay, and Erase trips,
Mark or save a position (Man Overboard), and
Measure the vessel's range and bearing to an object or location in the data file.

Some other features available in the WHEELHOUSE program, such as true vectors, were rejected by the DGPS Committee. However, that does not mean that they might not be considered again at a later date, or that they might not be suitable for use in a different waterway.

## MAINTENANCE, SERVICE, AND REPAIR

With the acquisition phase of the project complete, maintenance and repair has become the most time consuming part of the program. A service agreement between the Pilots' Association and RSC has been established to ensure that all of the Association's systems are maintained in peak condition. The service agreement provides for the rapid repair of systems needing service. The agreement also provides for annual operation checks and performance certifications of every system. Updates and upgrades to the software and equipment are performed at the time of these annual checks.

The most troublesome part and the weakest link of the navigation system has been the laptop computers. Approximately 25% of the laptops have needed service each year. The most common problem has been screen related failures. The Starlink DNAV-212 and MBA-2 Antenna have been extremely reliable, with less than 5% needing service since the start of the program in 1994.

Pilots with systems in need of service have corrective options available at all times. Any time a pilot's system is unusable or in for repair, the pilot may sign out one of the four spare systems the Association keeps available for this purpose. The spare systems kept for emergency use are equipped with water-tight hard cases. Simple things such as broken cables and lost adapters are corrected by the Association's Director of Operations while more severe problems are sent directly to the RSC. They determined the nature of the problem and decides the remedial measures to be taken. When repaired, RSC performs a system operation check and certification before returning the system to the pilot. Systems are turned in for repair complete as a whole; likewise, spare systems are taken intact. The use of parts from one system to repair another is not permitted. A supply of the most commonly damaged and lost parts is kept on hand with the

Association Director of Operations. The Association pays for all parts, repairs, service, and shipping; unless the problem was caused by the pilot's personal use of the equipment.

## TRAINING

The Pilots' Association will not issue a Portable DGPS System to a pilot unless he has completed the following training and orientation program:

- Attend and complete a 5 day DGPS / Shiphandling course at MITAGS. The first day of this course is devoted to GPS/DGPS theory and practice on the ship simulator using a replica of the laptop system in Delaware Bay scenarios. Capt. Bradley or one of the other DGPS Committee members supervises this first day of training. The remaining four days are spent on the simulator using various scenarios selected by the MITAGS instructors.
- Make at least one trip on the Delaware Bay or River with another pilot who is already equipped with the system. This trip may precede or follow the MITAGS course.
- Receive an orientation session with a pilot member of the DGPS Committee at the time the pilot receives his system.

In addition to the above requirements, the DGPS Committee has prepared a detailed instruction manual as a reference aid for pilots. This manual is issued with each system, and reviewed by the pilot and DCPS Committee member during the system orientation session. RSC provides Question & Answer sessions year round as availability permits, and Q & A sessions with operational refresher training during the annual service check at the Association's facilities.

## FUTURE PLANS

### HARDWARE

Some hardware enhancements available for the system are:

- reducing the physical size and weight through the use of newer and smaller components such as the TOSHIBA Libreno 50 CT mini-notebook computer;
- incorporating a heading sensor; and adding a digital radio link (transponder) that would transmit position, course, and speed information directly from one vessel to another. (The use of transponders may not go beyond experimentation pending a decision on the national level with respect to standards and carriage requirements.)

With the addition of cellular modems, pilots will be able to download real-time tide and traffic information from the Pilots' Association Computer Network. A limited amount of traffic data is presently available by this method. Upon completion of the upgrade to the Association's computer network, pilots will be able to download and display complete real-time traffic reports. Real-time tide data will be available once upgrades to the local tide reporting system are complete.

Further reductions in the size of the receiver and antenna may be possible in the next several years. However, the Association is not presently contemplating the replacement of these components due to their long service life (more than 10 years) and the expected cost of their replacement.

The use of infra-red or other non-cable methods for connecting the antenna to the receiver is also possible. The Association believes that the present coaxial cable connection is best because it is less complicated and more reliable than any other method of connection.

SOFTWARE

The flexibility of today's generation of laptop computer enables software enhancements to be virtually limitless. Planned for future versions of WHEELHOUSE are: user definable annotations, turning circles for aiding docking, and satellite maps in place of the satellite data table. RSC or Starlink should be contacted for more complete lists of available and planned features.

Other software programs available are:

- Tides & Currents for Windows - This is a very good tide and current prediction program that many pilots have purchased and loaded on their computers.
- NavMaster III / IV - NavMaster is typical of the electronic chart programs reviewed by the committee. The Pilots' Association believes that charting programs, such as NavMaster, should not be used in preference to Starlink's WHEELHOUSE in the Delaware River.

SUMMARY

The Pilots' Association For The Bay and River Delaware strongly believes that the decision to proceed with the development and acquisition of the Starlink Portable DGPS System has greatly enhanced the safety of navigation on the Delaware Bay and River. The Pilots' Association is proud to have been pioneers in the development of this revolutionary technology, and plans on being active in the development and implementation of future technologies.

## 5.3 ASSOCIATION OF MARYLAND PILOTS

The following contribution by Captain Richard Morrison details the PEPA experience of the Association of Maryland Pilots.

### DIFFERENT MANUFACTURERS AND SYSTEMS CONSIDERED

The Association of Maryland Pilots has been researching portable DGPS units for about three years. Shortly after Captain Joe Bradley of the Delaware Pilots invited me to his DGPS class at MITAGS the Association made contact with Chuck Parker of Raytheon Service Company and David Fowler of Starlink Incorporated. I worked with these men to customize the Starlink software for our pilotage routes. During this same time we also considered the following manufacturers:

- Trimble - They sent a unit for evaluation. It was not really intended to be a portable unit. Trimble also did not show any interest in customizing a unit for pilot use.
- Northstar - They sent a unit for evaluation (model # 941x). This unit also was not intended to be a portable unit, but they did put it in a waterproof carrying case and did show some interest in pilots. They displayed their equipment at the 1994 APA convention. They did not customize their software for pilots. They had to use the Starlink dual antenna and the quality of their DGPS receiver was inferior compared to Starlink's.
- "Portray" by Oceana Advanced Industries Ltd. was also at the 1994 APA convention. This unit is a true portable unit designed for pilots. It is a proprietary hand held unit, (meaning that you can not use any off the shelf software like the NOAA digitized nautical charts etc.) This unit was about five times the cost of a Starlink unit.

### SPECIAL NEEDS OF THE PORT

Baltimore has two pilotage routes: 1) The northern route consists of 50 miles of narrow channels from the C & D Canal to the port. 2) The southern bay route is 150 miles long, consisting of 50 miles of channels 700 to 1000 feet wide and 100 miles of more open bay where the ships follow the natural deep water course of the old river bed. In the upper bay we have fresh water that can freeze hard in winter. The ice can build up in the narrow channels. The standard buoys are replaced in the winter by small ice buoys. The combination of fog, ice and strong current can make these narrow channels very difficult to navigate particularly when passing other vessels. The lower bay is long and while it may appear wide the deep water route is narrow and the buoys that mark it are spaced several miles apart. In reduced visibility during fishing season it can be difficult to determine which target on the radar is the buoy due to all the small boat traffic. The Pilot Association has added to the computer a software program to display nautical charts. These NOAA raster charts are very useful in the open bay to show the depth curves and other chart information. Having a tool that gives the location of your vessel with respect to the centerline of the channel and to the location of the buoys is very helpful.

### SPECIFIC FEATURES / CAPABILITIES DESIRED OF THE EQUIPMENT

- Easy to use.
- All units to have the same waypoints to designate the centerline of all the channels.
- All units powered by ship's AC. Battery power not suitable due to our long pilotage.
- Unit must clearly show cross track error in feet.

- Unit must clearly show distance to next waypoint in feet at ranges less than a mile.
- Display screen should be an active matrix to improve the readability of information in bright sunlight.
- Have good display dimming feature for night display.
- Large readout showing important information (no need for reading glasses).

REASONS WHY RAYTHEON SERVICE COMPANY AND STARLINK EQUIPMENT WERE SELECTED

- Equipment answered needs of Pilots.
- Superior quality of equipment.
- Excellent service.
- Excellent customer support in customizing software for our port.
- Excellent customer support in maintenance and upgrades.
- Excellent customer phone support - (Excellent call back record).

CHIEF FACTORS WHICH DROVE THE SELECTION DECISIONS

- The product worked very well.
- Excellent customer support.
- Combined superior quality differential and GPS receivers.
- Superior dual channel differential receiver that receives one differential beacon signal while the other channel scans the other selected stations for a possible better signal.
- Excellent dual antenna (both differential and GPS antennas are combined into one mount using a single antenna cable).

COST OF EQUIPMENT

The Starlink unit with a 486 SX Toshiba notebook (model T3400CT) with 12 megs of ram costs $7800. The newer Starlink unit with a Pentium Toshiba notebook (model 610CT) costs about $10,000.

MANUFACTURER'S CLAIMS AND ASSOCIATION'S EXPECTATIONS OF THE SYSTEM

The equipment was operational when the Association of Maryland Pilots made contact with Starlink. Therefore, we were not involved in the initial development of the DGPS unit.

MANUFACTURER'S COOPERATION BEFORE, DURING AND AFTER INSTALLATION

Both Starlink & Raytheon have been very cooperative in all stages of the project, customization, modifications, and maintenance.

ANY DELIVERY PROBLEMS

The only problem encountered has been the laptop manufacturer Toshiba's discontinuing production of our early model notebook computer. The newer GPS units are using a more expensive and more powerful Pentium notebook which has a larger display screen and runs the NOAA charts program faster.

## IMPRESSIONS OF THE SYSTEM

We have been using the units now for about three years. The hardware and software have changed and improved during this time. We started out carrying the units in knap sacks. Now the equipment is carried in a waterproof ABS plastic case that floats. The DNAV 212 receiver is now smaller than the original unit. The original notebook computer was a 386 SX with a monochrome screen. At first I was always checking the accuracy of the unit's positions against known positions. Later, I found myself checking the unit to see if I was correct. The system is very accurate.

## ANY UNANTICIPATED INSTALLATION PROBLEMS OR DELAYS EXPERIENCED

I can think of only one software update delay when one software programmer quit Starlink unexpectedly. Due to Starlink's increased business there was a delay in some updated waypoint changes we had asked for. These updated waypoints were not of a critical nature and I did not press for them.

## THE ACCEPTANCE AND INTEREST OF THE ASSOCIATION AS A WHOLE AND OF INDIVIDUAL PILOTS EXPOSED TO THE SYSTEM

Many Pilots were skeptical of the accuracy of the unit. Once they saw the units in use in the channels and could compare the unit's cross track error with range lights they were impressed. There seemed to be a little more hesitance to use the units by pilots who had never used a computer before. But due to the simple nature of the unit's operation the learning curve was short. DGPS navigation offers pilots a new and different way of determining the vessel's position. Pilots that have used traditional methods of piloting for many years may find it some what harder to accept this new aid. We all understand that DGPS is only an aid to navigation. It cannot replace the need for an experienced local pilot. Merely having a DGPS unit does not make one a skilled pilot. A good pilot rarely makes a decision based on one aid. Pilots draw on their expertise acquired over years of service in their local waterways.

## THE MAJOR FACTORS AFFECTING THE ACCEPTANCE OF THE EQUIPMENT

After pilots are convinced that the unit works and is useful, they have to be convinced that it is worth the expense and that the weight of the unit is light enough to carry aboard all vessels. Some pilots want to wait for the units to become smaller, lighter and to cost only one thousand dollars or until all ships have DGPS units onboard. Most pilots will be retired before the unit changes this much. If all ships ever installed Differential GPS units onboard it is very unlikely that the waypoints for the centerline of the channels will be the same on all ships. It is safer for pilots to use the same unit that they are familiar with and trust.

## TRAINING OR ASSISTANCE NEEDED AND / OR FOUND TO BE USEFUL

Training is a very important element in the use of the units. When-ever pilots are on the bridge of a vessel they are responsible for their actions. If they are using electronic equipment such as radar or GPS and they are not trained in its use they can be found liable. All of the Maryland Pilots have taken a course at MITAGS on DGPS and how the Starlink unit and software work.

They have also all taken a course in the use of the digitized NOAA charts run with the Mariner chart program. This training greatly reduces the pilot learning curve. It puts pilots on the bridge with a good knowledge and understanding of the equipment. We also have used our well trained apprentice pilots to assist senior pilots in onboard practice with the unit. With the apprentice's help the pilots are not distracted from their piloting duties during the initial period of becoming more familiar with the operation of the unit. It takes a little practice to learn when and where to setup the unit and the antenna, especially on a dark bridge.

## ANY PROBLEMS WHICH AROSE IN THE UTILIZATION OF THE EQUIPMENT AND SOLUTIONS FOUND FOR THEIR RESOLUTION

The batteries in the notebook computer were a problem. The Starlink system is set up to use ship's AC power (100 to 240 volts). The problem was that if the ship's power was cut off the GPS stopped working but the notebook computer would continue to run due to the battery that came with the computer. The chart was still shown on the screen but the vessel's position was not being updated by the GPS. There is a notice in the upper corner that there was no GPS signal. If the pilot did not see this notice, the display could be very misleading. This problem was resolved by replacing the notebook battery with a blank battery. This action also reduced heat and the weight of the unit by about a pound.

The brightness of Windows programs was a problem on a dark bridge. The night screen of the notebook can be controlled by the Starlink program. Controls for brightness and contrast of the Starlink program are not a problem because the program is a DOS based program. The problem comes when running window based programs like chart programs. It is not possible to control the brightness of these program displays. At night on a dark bridge the displays are too bright. These chart programs have a night mode screen that changes the display to red & black. This display is very hard to read. A better solution I have found is to use the day mode display and cover the bright display with a smoked vinyl sheet.

## THE PROSPECTS FOR FUTURE UTILIZATION AND / OR IMPROVEMENTS OF THE EQUIPMENT FOR THE PORT - (WISH LIST FOR FUTURE UNITS)

- Lighten but maintain a strong and waterproof carrying case.
- Back light the keyboard and use a rheostat to control the brightness.
- Use stranded wire in the antenna cable in order to make it more flexible.
- Make it possible to switch back and forth between the Starlink program and a NOAA chart program without closing down one of the programs. This presently cannot be done because Windows will not allow more than one program to use the input serial port at a time.

## 5.4 CHARLESTON BRANCH PILOTS

The following contribution from Captain Daniel Waldeck details the Charleston Branch Pilots Association's experience with PEPA technology.

> My involvement with our DGPS unit began when the unit was delivered in May of 1996. Before the unit's arrival, Captain Robert H. Lockwood had been responsible for the research and planning for our unit. After discussing his findings and experience with the unit, we decided that I would write this report and relay his impressions and findings.
>
> Captain. Lockwood's decision to use Raytheon came after researching five different companies that offer similar products. He chose Raytheon because they already have units working on other pilotage waters. With some of the other companies, Charleston would have been their first project. While these companies had the expertise to construct a DGPS unit, they lacked the experience with developing units for pilot associations. Captain Lockwood did not ask for any special features or insist on any extra capabilities when he ordered the unit. The total cost of the unit was approximately seven thousand dollars.
>
> Mr. Charles (Chuck) Parker from Raytheon Service Company arrived in Charleston with the unit around May 1, 1996. Mr. Parker instructed me on use of the unit, with the idea that I would be able to show other pilots how to setup and use the unit once he left. Most pilots found the unit fairly easy to learn how to use. Chuck Parker, myself, and the duty pilot made a few trips with the unit on board. We found some significant problems with the programmed data. The data used was a conglomerate of computer information obtained by Chuck from the Army Corps of Engineers and U. S. Coast Guard. We found that the positions of some buoys and ranges were inaccurate. We have notified the Coast Guard and informed them of the inaccuracy of some of the positions they listed in their data base.
>
> The inaccurate data presented a number of problems for us, such as: unit acceptance, effective usage, delays, and problem resolution. The unit was found to be very interesting, but I do not believe many pilots trusted the unit, due to the inaccurate data. After determining that the data was off in several locations, I felt that any further use by pilots could be detrimental to their opinion of the unit.
>
> We spent a lot of time working to evaluate the extent of the inaccuracies and how we were going to correct them. The first choice, which we did pursue, was to contact the U. S. Coast Guard about the inaccurate data. The time required for them to correct the aids, then report them in a Notice to Mariners could easily have taken months. Faced with this prospect for delay, we then decided to program the unit with the actual positions of the floating and fixed aids. We accomplished this by positioning our DGPS receiver to within a few feet of the aid in question, and recording its position. Mr. Parker then programmed this new data into our unit. This was done with reluctance by all involved, but it was the obvious choice if we wanted to get our system up and running in 1996.
>
> This process was tedious and exhausting, but the end product was satisfying. We now have a system which is accurate to within a few feet. In addition to position adjustments that Mr. Parker and I made in August, 1996, there were several others. We installed bridges, anchorages, new routes and adjusted the menu screen. This second trip to Charleston by Mr. Parker was extremely valuable in solving the large problems we had experienced with the unit. After making the changes and testing the system out several times, I have a new faith in the unit's accuracy.

Another problem we encountered was the unit's poor transportability. The unit is heavy and awkward, and makes embarking and disembarking ships more dangerous. Next generations of portable DGPS should be lighter and be more compact.

The setup of the unit also needs to be simplified. At night, the rigging of antenna wires and finding a power source is extremely difficult, especially when trying to drive a ship at the same time. A more portable DGPS unit would be one that has a computer processor, GPS receiver, color display, and keyboard in one small, slim unit. This would minimize wires, size and, hopefully weight.

Since delivery of the unit, the Association as a whole, has not had much experience with it. This is mostly due to the time involved in adjusting the unit's position data. Even though the unit is accurate, the weight and setup involved does not make this unit very popular. I believe all of the pilots realize the tremendous benefit of DGPS, but the current unit is not considered "user friendly".

There is little doubt that DGPS will be extremely beneficial as another navigational aid for the pilot. It is my belief that many pilots will carry this unit once it is made lighter and easier to carry.

## 5.5 TAMPA BAY PILOTS ASSOCIATION

The following contribution by Captain Brian Tahaney of the Tampa Bay Pilots Association details his concerns and experience with PEPA technology.

> The following comprises my evaluation of the Ross Engineering DSCIAISIADS Portable Electronic Piloting Aid. Although I have also tested the Raytheon prototype and a similar unit manufactured by Cybernautix, I have found the Ross unit to be clearly superior to these units in both technological design and user friendliness. Although I found the Raytheon unit to be quite accurate and user friendly, I personally feel that the unit lacks some very significant features, the most significant of which is the inability of the user to view the position and movement of other vessels in the system. With the Ross system, the user can view any vessel in the system equipped with either a DSC radio or one of the Ross portable or fixed installation units. This surveillance capability is critical when these systems are incorporated with Vessel Traffic Information Service (VTIS) Systems. The Ross system also provides real time data on tides and current information provided by the PORTS[11] system in Tampa Bay and real time visual weather tracking from a local Doppler radar. The speed at which this information is transmitted greatly increases the accuracy of the unit and availability of critical information on a timely basis. I tested the Cybernautix unit only 2-3 times and experienced problems with the unit each time. Both the Raytheon and Cybernautix unit also lack the wireless technology[12] which allows the unit to be setup and broken down in a timely fashion. This lack is critical because it reduces the time frame in which the pilot is distracted from his/her traditional duties.
>
> There were other vendors such as Lopos (West Germany) and Oceana (Israel) and Arinc (U.S.) who presented their concepts to the maritime community in Tampa but have never actually provided a unit for testing purposes. Maritrans Inc. had previously been using the Accupoint Ground Guard system which broadcasts on an FM carrier frequency and also had a Ross unit permanently installed on the tug *Freedom*. They have requested many Ross units for their vessels. The majority of the pilots in the Tampa Bay Pilots Association agreed to participate in an experiment to determine the effectiveness of the Ross Portable Unit, to commence sometime in mid to late November, 1997. At this time there will be an adequate number of portable units provided by the Ross/Northrup Grumman Partnership for all pilots wishing to participate. The unit is currently being redesigned to reduce the weight from 32 lbs. to 17 lbs. for ease of carrying Weight has been the major complaint about the unit. A new high technology heading sensor is also being added, which many pilots felt was highly desirable, especially in turns and at low speeds when significant crabbing was in effect. Fixed units will also be installed on various Maritrans tugboats as well as on vessels of certain U.S. Flag tanker operators who have agreed to participate in the experiment as well. The experiment will be for some 60-90 days and then the unit will be further evaluated in terms of it's effectiveness.
>
> Personally, I endorse the Ross Piloting Aid for a variety of reasons I would like to share with the American Pilots Association. I have recently spent a great deal of time reviewing the upcoming

---

[11] The Physical Oceanographic Real-Time System (PORTS) is a program of the National Ocean Service that supports safe and cost-efficient navigation by providing ship masters and pilots with accurate real-time information required to avoid groundings and collisions. PORTS includes centralized data acquisition and dissemination systems that provide real-time water levels, currents, and other oceanographic and meteorological data from bays and harbors to the maritime user community in a variety of user friendly formats, including telephone voice response and Internet - Ed.

[12] Wireless technology refers to the capability of the hardware components of the system (computer, antenna/receiver) to communicate without being connected by wires, but rather radio waves – Ed.

changes to both U.S. and international maritime telecommunication regulations. I feel that any type of portable unit we consider using should have the ability to be easily interfaced with the upcoming new equipment that will be mandatory in 1999 for all SOLAS vessels. The Ross unit is the only portable piloting aid I am aware of that is already in compliance with several IMO regulations due to come into effect in 1999. As of February 1 1999, all SOLAS vessels will be required to be equipped with DSCIGMDSS systems in order to be in compliance with the GMDSS provision of the IMO SOLAS convention, which includes, among other things, ITU-R recommendations 493,541,821,823 and 825. These documents specify the technical characteristics of shipboard radiocommunications and radionavigation equipment to be utilized by the GMDSS and also in conjunction with ship-ship and ship-shore AIS (Automatic Identification Systems) and VTS (Vessel Traffic Systems). These provisions were instituted in order to insure world-wide interoperability within the GMDSS and within all ports equipped with VTS. Of particular importance is recommendation ITU-RM 825: "Characteristics of a Transponder System Using Digital Selective Calling Techniques For Use Within Vessel Traffic Services and Ship to Ship Identification". This document sets the minimum standard carriage requirements for transponders. The IMO NAV 41/42 initiative (IMO Safety of Navigation Committee) has requested the ITU-R to add specific details to Rec. 825 to facilitate the transmission of expanded VTS related ship-ship and ship-shore messaging and to improve the update rate of vessel position reporting. The ITU-R Working Party 8C has drafted modifications for approval at the next meeting in Geneva, October 29 - November 8, 1996. This action by the ITU-R will satisfy the requests of the IMO Nav 41/42 Committee. The Ross Unit already meets these detailed requirements, and it was demonstrated to the Radio Technical Commission for Maritime Services (RTCM) SC101 (Special Committee 101 on Digital Selective Calling, chaired by the U.S Coast Guard) at the August 1, 1996 meeting in Tampa, Florida. Both the U.S, and Canadian Coast Guards have adopted this new draft of Rec. 825 as the North American position in the IMO and the ITU, and the United Kingdom has indicated their agreement. Ross has also installed and is operating a radio tower in Tampa Bay which supports this new standard system.

All SOLAS ships will be required to have equipment with which they can automatically respond to an "all ships call" request by local VTS systems. The polling interval will be standard. The Ross unit has the capability to incorporate this "all ships call" data with it's own rapid polling data for vessels already participating in the local VTIS system. The positions of vessels in the system will be updated every 10 seconds (or some other appropriate polling interval) and vessels outside the system every 15 minutes. This would provide local VTS systems with a complete surveillance spectrum. It would also greatly enhance safety when approaching and departing a U.S. port. This would begin to address the concerns of Intertanko that U.S. ports lack effective VTS facilities. It would also be in keeping with the desire of the U.S.C.G. to enhance regulatory reform. This regulatory reform seeks to create harmony between U.S. and International regulations concerning many areas of the maritime industry. Enhanced safety in U.S. ports through effective VTS systems is just one facet of this regulatory reform. Using equipment that is ahead of it's time with respect to future IMO regulations would seem to be the logical path to follow. The desire to attain uniformity with the international maritime community is clearly stated in the Jan/Feb issue of PROCEEDINDS on pages 4-6.

In closing, I wish to be clear that these views are my own personal strong opinions. I am not in a position to speak for the Tampa Bay Pilots Association as a group, but I believe that many of the members of the association are in agreement with me on these points. I believe that the best way for the State Pilotage System in the U.S, to gain and maintain the respect we so desperately need is through strong leadership initiatives like this to enhance safety in our ports. If we take the lead in implementing equipment and systems that are in keeping with the new emerging international standards, we can "get ahead of the wave" and, hopefully, stay there by keeping ourselves in step with the best current advanced technology and rulemaking. We now have a rare and unique opportunity to insure that our own professional substance and our image is further established.

## 5.6 NY/NJ - SANDY HOOK PILOTS

The following contribution from Captain Andrew McGovern details the NY/NJ Sandy Hook Pilot Association's experience and Northeast Marine Pilot's experience with PEPA technology.

The Sandy Hook Pilots reviewed the literature supplied by all the manufacturers for this evaluation project and gave serious consideration to two manufacturers. After visits from these two manufacturers, the team of Raytheon/Starlink was chosen.

The choice was a tough one. The other unit considered was a proprietary unit (the advantages of this type of design being size, weight and ease of use/ergonomics), unfortunately, the major disadvantages (the inability to adapt the unit to rapid improvements in technology and use of the laptop computer for other purposes such as logs, billing, etc.) outweighed the advantages.

The Raytheon/Starlink unit was chosen over other open architecture units for many reasons:

- compatibility with other units on the east coast
- integrity of the software
- experience
- support from the company representative

The Port of NY\NJ is large and complex with channels ranging from wide to very narrow. As per Murphy's Law the significant large tanker traffic moves primarily through the narrow channels. The Sandy Hook Pilots feel the portable unit is extremely valuable while transiting these channels as well as the larger ones. The main purpose of the unit is to monitor one's position within the port as well as one's position relative to the channel centerline. These functions are especially useful:

- during meeting and passing situations
- during times of reduced visibility due to heavy rain or snow (which will tend to degrade the radar picture to a point of uselessness)
- during times of good visibility due to the USCG's refusal to make public the accuracy classifications of the buoys marking the outside limits of these narrow channels.

The most difficult and time-consuming part of the installation process was obtaining the information needed to build the source charts required by Raytheon/Starlink. Two government agencies were involved in our quest for the correct data. From the Army Corps of Engineers (ACOE), we needed to obtain the channel centerline data in the correct datum (NAD 83), and from the USCG we needed the assigned position (AP) of the buoys in the same DGPS/NAD83 format. The ACOE, while cooperative, is short staffed, and they had to build custom charts with this data, which took time. The USCG on the other hand was not cooperative on a district level. When the information needed was requested from the first district we were assured it would be forthcoming, but it never came. When I finally inquired on a local level, after having no luck with the district, I was informed that the district had no intention of releasing the information for liability reasons. I was finally able to obtain the information on the local level through a Freedom Of Information Act request.

The Boards of Commissioners of Pilots of both the State of NY and NJ, while fully supporting the concept of the portable pilot unit, initially had grave misgivings about its use, abuse and accuracy. After many demonstrations, negotiations, changes to the software and potential additional training, pilots were able to test the unit on board vessels during actual piloting assignments.

Source data from the ACOE and the USCG made for an extremely accurate position fix relative to the channel. Raytheon/Starlink's insistence on using this source data is well founded. If one were to use a standard NOAA chart that had been digitized, the potential for having a DGPS assisted grounding or collision is great, because the surveys from which the chart is based are not accurate enough to be used with DGPS in a harbor situation.

As with any new technology or piece of equipment, training in its use, limitations, and theory is required before the unit can be used properly.

A major problem rendering the unit inoperable in the DGPS mode for most of July and August of' 1996 was the sensitivity of the USCG DGPS transmitter to humidity, rendering the beacon transmitter inoperable. Also discovered, after this episode, was a hidden glitch in the software which would not allow the differential unit to switch to another frequency if the primary transmitter went down instead of gradually losing signal strength.

Raytheon/Starlink has been very committed to supporting our unit and improving it. The company representative continues upgrading our unit with the latest improvements and seeking our input for continuing improvement (such as making the program windows based).

The Sandy Hook Pilots see the unit as a stepping stone for a voiceless VTS in the near future. (We see this as a cheaper option to the heavily manned systems of today, while decreasing the chance of human interpretive error). A pilot will be able to view the exact location of his/her vessel - as well as the locations and information (name, SOG, COG, etc.) of all the other users of the port - by means of AIS or radar information transmitted to the unit. The pilot will also be able to access other pertinent waterway information, such as PORTS[13], with the unit.

[13] The Physical Oceanographic Real-Time System (PORTS) is a program of the National Ocean Service that supports safe and cost-efficient navigation by providing ship masters and pilots with accurate real-time information required to avoid groundings and collisions. PORTS includes centralized data acquisition and dissemination systems that provide real-time water levels, currents, and other oceanographic and meteorological data from bays and harbors to the maritime user community in a variety of user friendly formats, including telephone voice response and Internet - Ed.

## 5.7 NORTHEAST MARINE PILOTS

The following contribution from Captain Andrew McGovern details the Northeast Marine Pilots experience with PEPA technology.

> The area of responsibility is large and varying: from the wide open areas of the Long Island and Block Island Sounds to the small harbors of New Haven and Providence, extending to the Cape Cod Canal.
>
> The Association did not look into various manufacturers, but instead relyed on the experience of other associations (Maryland, Delaware and Sandy Hook) and selected the Raytheon/Starlink unit for evaluation. The lead evaluation pilot, Captain Mike Ball, is extremely happy with his decision both from an equipment standpoint as well as from a company's representative perspective. Chuck Parker's knowledge, support and cooperation before, during, and after purchase of the unit has been phenomenal.
>
> As information is not available on channel centerlines in areas such as Long Island Sound, a combination of NOAA based charts and source charts must be used to obtain full coverage of the area.
>
> The only problem encountered before delivery was that of getting the necessary information from the various government agencies to build the source charts. After a long delay the agencies were cooperative. After delivery there were some small software glitches which were addressed quickly.
>
> Initial training on the use of the unit was provided by the manufacturer's representative.
>
> During initial utilization, some of the problems encountered were;
>
> - lengthy set up time (though this gets shorter with experience)
> - loosing the DGPS signal intermittently
> - the NOAA based chart program being only OK - if one zooms out in order to view a larger portion of the chart the print is to small to read
>
> The NOAA based chart program needs improvement, and this is being done continuously.
>
> Capt. Ball has been surveying various docks with a backpack version of the unit. This information is being integrated into the program. Other program enhancements include a rewind feature to allow playback of various aspects of a transit as a teaching aid and the addition of a variable length vector, bringing the presently used version to 6.64.

## 5.8 HOUSTON PILOTS DGPS PORTABLE UNIT

The following contribution by Captain Joseph Warfield details the Houston Pilots experience with PEPA technology.

> Prior to the Portable Electronic Piloting Aid Project, the Houston Pilots had been working with the Port of Houston Authority and Hydrographic Associates Inc. using a shipboard Houston Area Navigation System (HANS) unit. We decided to continue with HANS as a portable unit for the project.
>
> Our HANS unit for the project utilized a Starlink receiver and a Sharp computer with a color display. The cost of the unit was just over eight thousand dollars.
>
> The pilots' needs in the portable unit were the same as for the fixed system already developed. An accurate chart was needed showing the channel, aids to navigation, docks, and other information. We wanted the unit to show vessel position in the channel, with distance left and right of the channel centerline. We also wanted the portable to show the ship to scale, but could not get heading information.
>
> The electronic chart above Baytown, Texas, had to be made and the earlier chart corrected. Data for the chart was Corps of Engineers information, Coast Guard data on aids to navigation, and our own dock surveys using the unit. Some information on shorelines removed from the channel came from NOAA charts.
>
> There was good cooperation with the manufacturer, Hydrographic Associates Inc., throughout the project. The unit had a software problem when it lost GPS input and went into Dead Reckoning mode, which was corrected. Our unit was received on time and pilot evaluations were completed.
>
> As agreed with our project regional coordinator, our unit was rotated to the Galveston-Texas City Pilots, who later submitted evaluations.
>
> Formal training issues for pilot use of the unit were not addressed. We were participating in an evaluation only, and therefore did not embark upon a training program for our pilots. Pilots who volunteered to evaluate the unit were given operational instructions, and were not to use the unit in a way which would alter their normal piloting practices.
>
> Most of the pilots in Houston have not been exposed to firsthand use of the portable HANS. They have seen the unit demonstrated at meetings. The pilots who carried the unit feel that it is useful. To meet all of our needs, the unit should have heading information so that a ship to scale can be displayed. To date, there has been no acceptance or rejection of a DGPS portable by our group.
>
> When the Galveston-Texas City Pilots returned our unit, the Houston Pilots and the Aransas-Corpus Christi Pilots loaned the two HANS units to Mr. Colin Weeks of Hydrographic Associates Inc. Hydrographic Associates Inc. had received a grant from the Port of Houston Authority to develop a communications package for the HANS portable units. The pilot groups provided upgraded memory and interface cards for the units. Additionally, Houston Pilots provided pilot boats for communication trials, and the Galveston-Texas City Pilots and Corpus Christi Pilots provided the pilot operators of the units. A communications package was developed and our unit returned to us.

Our group is still evaluating any future prospects of using the system. To that end, our chart is being upgraded using aerial survey information, and we replaced our original unit's computer with an active display Toshiba laptop. Additionally, a second unit, the same as the upgraded original unit, has been purchased. Our members will decide any future use of DGPS portable units.

Should our group decide to adopt DGPS portables, then we will look at other issues such as formal pilot training, liability, ownership, service, and support.

## 5.9 ARANSAS - CORPUS CHRISTI PILOTS

William Parrish

The following contribution be Captain ~~Michael Kershaw~~ details the Aransas-Corpus Christi Pilot Association's experience with PEPA technology.

> The Aransas-Corpus Christi Pilots participated in the Marad-APA PEPA project utilizing a HANS (Houston Area Navigation System) portable pilotage system, which was purchased from Hydrographic Associates, Inc., of Houston, Texas. Purchase price of the DGPS unit was $8,118.00.
>
> The HANS portable pilotage system consisted of a Starlink DGPS receiver/antenna, Sharp Notebook computer, HANS software, power/battery supply, and carrying case. The HANS software consisted of an electronic chart program that was written by utilizing current NOAA charts, U.S. Army Corps of Engineers Corpus Christi Ship Channel Project data, and the Port of Corpus Christi channel data. The software was custom designed and utilized local pilot input in regards to display requirements and operational practicality.
>
> The choice of HANS as a system provider was based primarily on the ability of Hydrographic Associates to custom design the electronic chart, provide good initial/follow up training, a simple and reliable DGPS unit, and a competitive price. The manufacturer cooperated with personal attention before, during, and after the installation. Pilot-requested modifications in the software were undertaken and expeditiously carried out.
>
> First impressions of the HANS portable pilotage system were good. Most pilots in the group felt that it could serve as a useful positioning aid in piloting. The Corpus Christi Ship Channel is a narrow dredged waterway. Under normal weather conditions, fixing the vessel's position is not difficult to ascertain due to adequate aids to the navigation system. During periods of low visibility (fog/rain) the DGPS system would be most useful in our piloting scenario.
>
> Four pilots tested the system in the Corpus Christi Channel. All found the unit to perform up to it's stated capabilities. The major problems that confronted the testing pilots involved the following:
>
> 1. Portability of the unit (single carrying case, weight 25 lbs.) More portability and less components would be an asset.
> 2. Initial set up of the unit (antenna positioning, power interface, and actuating the program with ship data). Initial set up divides the pilot's time when he is trying to take command of the vessel he is to pilot.
> 3. DGPS interface with the ship's gyro compass. Lacking a gyro interface, the unit's display does not show instantaneous changes in ship's heading on the display. This is a problem especially at speeds under 5 knots.
>
> Although the HANS system was lacking in the above mentioned areas of operation, it did serve as a very accurate method of ship positioning. With the advent of future improvements in DGPS portable systems, along with the ability of interfacing them with future vessel traffic systems, the prospect of future utilization in the Port of Corpus Christi is definitely a viable consideration.

## 5.10 REPORT ON PORTABLE ELECTRONIC PILOT AID (PEPA) GREAT LAKES REGION

The following contribution by Captain Donald Willecke details the Western Great Lakes Pilots' experience with PEPA technology.

When the APA-MARAD study commenced, the Great Lakes Region considered two PEPA units. The Raytheon Starlink unit was one, the other was a unit from Astronautics Corporation of America. I chose the Astronautics unit for two reasons. One, the manufacturer is located in Milwaukee, Wisconsin in the heart of our Pilotage District. Second, Astronautics has extensive experience with military as well as spacecraft guidance systems that I thought would possibly give their unit some advantages of cutting edge technology that might not be available to other vendors. Astronautics works in conjunction with the State Research Center of Russian Federation, "Electropribor", in the development of their software.

I picked up our unit in Milwaukee in March of 1996. It consists of an ACERNOTE 950 notebook computer with 75 mhz Pentium processor, a Communications Systems international (CSI) GPS/Differential beacon receiver, a sealed lead acid battery for the GPS receiver, and a magnetic mount antenna and cables. The unit is transported via a soft sided attache for the computer, and a hard shell case that contains the rest of the equipment. A single case that will accommodate all of the equipment is being manufactured. The weight of the unit (including cases) is 36.2 lbs. In my opinion this is the biggest deterrent to this unit. The cost of the unit is $7,500.

The unit is to be tested in the St. Mary's River in the Upper Peninsula of Michigan. This river is approximately 50 miles long and possesses many hazards to navigation including narrow channels, strong currents, and a lock. The weather here changes very quickly due to the effects of Lakes Superior, Michigan, and Huron. Fog is a major problem in the spring and autumn when the air temperature and water temperature differ greatly. The river is closed in the winter due to ice, and as a result, the floating aids to navigation are pulled in the fall to prevent damage. This adds to the usefulness of a PEPA.

The St. Mary's River is covered by three NOAA charts (14882, 14883, 14884). Astronautics had its Russian counterparts digitize these charts. Unfortunately, they only got two of the three charts completed, and I didn't receive the charts until late August of 1996.

Once the charts were installed, we had a problem getting the equipment to work. Astronautics was rewriting their operator's manual, and the program was difficult to learn. Once our software operating problems were solved over the phone, we had a hardware problem with the GPS unit. It was sent to Canada to be repaired, and by the time it was returned the shipping season was nearly over. I did manage to use it three times before the end-of the 1996 shipping season, but each time it showed the vessel's position to be 500 feet to the left of its true position. I tried to get Astronautics people up to Michigan to see what was wrong with the unit, but our schedules never seemed to coincide.

At the beginning of the 1997 shipping season (Late March) it was decided that we needed to have an operational unit to test so at least we could get some evaluation done before the end of the study. I contacted Raytheon/Starlink. and contracted Chuck Parker to provide a unit for us. With this unit the charts are constructed from the raw Corps of Engineers, and U.S. Coast Guard data. This is a very time consuming process, and the most difficult part of the process is getting the information from the Government authorities. It seems that in this age of liability and litigation, the Coast Guard is reluctant to even give out the position of its aids to navigation for fear of liability in the case of a marine casualty. Because of this difficulty, and the fact that some of this data does not even exist, this unit will not be delivered to us until August, after the evaluation period is officially over.

In the meantime, we have fixed the problems with the Astronautics unit. It was not a problem with the vendor's software, but with the charts. It seems that a conversion factor was not applied to the charts, and this was producing the error that we incurred. Of course, now that the evaluation has concluded the unit is working perfectly.

With the limited use that we've had of the unit, we don't have any long term impressions, but these units definitely have a future in our area. I have had the opportunity to use the unit when fog set in, with zero visibility. This is where the unit served its purpose flawlessly. When making turns in narrow channels, it took most of the stress out of the situation. When using the ship's radar, it is difficult to make turns in close proximity to buoys or objects. By glancing at the unit, it was greatly reassuring. It took the guesswork out of our exact position, and has truly taken the stress out of a traditionally more apprehensive situation. This fact in itself makes the unit worthwhile.

The major drawback to the Astronautics unit is the weight of the unit. Companies like Raytheon have developed their units over time, and have gotten theirs down to less than 20 lbs. This is manageable, and makes it no problem to take the unit on board ship.

Like any new technology, acceptance can be slow. There has been unusually strong pressure in recent years from shore based managers to use new technology to eliminate shipboard personnel, including pilots. Many have sited DGPS technology as the means to this end. Most people who propose this, however, are not involved in the navigation or piloting of a vessel, but managers that are simply interested in cutting costs. Once it is realized that this is a tool to help the pilot do his job more safely, not a replacement for him, acceptance will be strong.

I feel that there is a future for this technology in the Great Lakes area. With the Coast Guard cutting down on aids to navigation, adverse weather, and the pulling of buoys in the fall, this unit's usefulness and acceptance will only increase

## 5.11 PACIFIC COAST

The following contribution by Captain Carl Bowler of the San Francisco Bar Pilots details the U.S. Pacific Coast experience with PEPA technology.

> San Francisco Bar, Southwest Alaska, and Southeast Alaska Pilot Groups were three designated Groups for evaluating on APA/MarAd Portable Electronic Piloting Unit.
>
> All of the Associations selected units being developed by D. F. Crane and Associates of San Diego California. D.F. Crane was a successful developer of small boat navigation systems including hardware and navigation software. The company had been involved in research programs with the US Coast Guard looking to further develop navigation technology on larger vessels. His systems were installed aboard both U.S. Coast Guard Cutters and large commercial vessels.
>
> Dave Crane expressed an interested in developing Portable Navigation Systems and, after some discussion, he agreed to undertake the development of a wireless system. The wireless feature of a system was particularly attractive to the Alaskan Associations due to the relatively hostile environment. For these and other reasons all three associations selected Dave Crane to provide piloting units for the evaluation.
>
> The development process occurred in two areas, hardware and upgrading his successful navigation program to incorporate features useful to pilots. Hardware development was by far the biggest challenge. A number of attempts were made to develop an efficient lightweight wireless transceiver. The often opposing objectives of light weight, long battery life, and power requirements proved to be a daunting challenge. Succeeding models seemed to improve weight and/or reliability) but in the end the goal of an efficient lightweight antenna was never fully achieved. Simultaneously, Dave Crane upgraded the small craft navigation software to incorporate features suggested by pilots using the program.
>
> In January of 1997 Dave Crane closed his business thereby halting any further development of his system. This effectively ended the West Coast`s participation in the evaluation project
>
> Although we are no longer actively involved in the evaluation project, we have had enough experience with the technology to recognize how valuable the technology is as another tool for navigation. There are successful systems that are being used by Pilot Groups in other parts of the country. The State of California, Office of Oil Spill Prevention And Response, has recently expressed an interest in evaluating Portable Piloting Systems for use by pilots in San Francisco Bay. Therefore we hope to continue the effort to develop and utilize this technology to enhance vessel safety in the Bay Area

# 6
# EVALUATION

## 6.1 BACKGROUND

The main focus of the Piloting Cooperative's Portable Electronic Piloting Aid Project involved an evaluation of established and prototype commercially-manufactured portable units by working pilots in ports throughout the United States. Such a qualitative evaluation by the end users of the technology in actual working practice was determined by the members of the Piloting Cooperative as the best way to assess the utility of this new technology and gain some insight into its impact on the practice of piloting.

In order to insure an equitable national geographic representation for the evaluation, the country was broken down into five regions: North Atlantic, South Atlantic, Gulf Coast, Pacific Coast, and Great Lakes. From these regions specific ports for portable electronic piloting aid technology evaluation were identified in April of 1996. The pilot associations selected to participate within each region were done so on the basis of: type of waterway and geography of the port, known unique piloting challenges/conditions where the application of the technology was anticipated to yield valuable data, experience of the pilot association with the technology, interest of the pilot association in the technology, and willingness of the association to participate in the evaluation. The ports selected involved a full range of piloting operations and navigational challenges, from the confined waters of the Mississippi River at New Orleans and the Houston Ship Channel to the comparatively open water sections of the Delaware, Chesapeake, and Tampa Bays. Two of eleven participating associations, the Association of Maryland pilots and the Bay and River Delaware Pilots, were already well along in installing portable systems with each pilot in their association. These two associations contributed the majority of data for the evaluation.

In April, 1996, a working group made up of five members of the Cooperative completed up a 15 page Evaluation Form designed to address the pertinent evaluation topics, among them:

- The physical characteristics of the units
- The logistical considerations of the units in transport and operation
- The user-friendliness of the units in transport and operation
- The accuracy and usefulness of the information provided by the units
- The comparison between the information provided by the units and information provided by the ship's equipment
- Conditions of use for the units
- The reliability of the units in providing accurate information
- Identification of the most helpful features of the units
- Primary criticisms of the units
- Suggested improvements to the units
- Assessments of the efficiency and safety-related factors for working pilots
- Training considerations for proper unit use

- Effects of the unit on the practice of piloting

These evaluation forms were distributed to the test ports for their earliest completion. The evaluation period was originally established at six months, but was subsequently extended for six more months to accommodate certain test ports experiencing manufacturer delays in getting equipment on the water for evaluation. Some of these ports responsible for the extension never got equipment on the water for evaluation for a number of different reasons (See Section 5).

## 6.2 OVERVIEW

The evaluation was based on responses received from 70 pilots, between June 1996 – June 1997, who used units from four different manufacturers in 11 U.S. ports on a total of 4,125 transits, with a median use of 30 transits each. They responded to a self-administered survey containing 54 questions that included both closed-end and open-end opportunities to respond. The evaluation form contained 12 demographic and environmental variables that described the characteristics and experience of the pilots. It also contained 121 variables that pertained to the physical characteristics and operation of the DGPS units, the presentation and accuracy of information, and the usefulness of the units to various piloting tasks. The form also included 8 open-ended questions asking for summary conclusions and observations about the units.

The responses show a very high degree of agreement on most questions. Analysis of subgroups revealed no statistically significant differences when comparing pilots on age, years of experience, number of transits with the unit, types of waterway piloted, or type of manufacturer unit used. This correlation is not surprising given the comparatively small sample size and the fact that most pilots were using the same unit (Raytheon/Starlink DNAV 212 running on a Toshiba 3400CT laptop computer). Further, most of the pilots were operating on the same bodies of water (Chesapeake Bay, Delaware Bay, and the Chesapeake and Delaware Canal). A larger and more diverse sample would be required for a more valid comparative test of different units, or of the effects of different combinations of age, experience, and circumstances. As such, comparative analysis between the different units and other factor combinations is not provided.

Nonetheless, it is important to recognize that a null finding (i.e., no differences in responses) is still a valid and useful finding. The pilots who have used DGPS units have substantially similar experiences. Younger pilots agree with older ones. Relatively new pilots agree with much more experienced ones. Those who have used the units for many transits agree with those who have used the units for only a few transits.

## 6.3 DEMOGRAPHICS

A total number of 70 pilots responded to the survey.

They belonged to eleven different pilot associations:

- 44.3% (31) Association of Maryland Pilots
- 22.9% (16) Bay and River Delaware Pilots
- 7.1% (5) Tampa Bay Pilots
- 5.7% (4) Houston Pilots
- 4.3% (3) Aransas-Corpus Christi Pilots
- 4.3% (3) NY/NJ Sandy Hook Pilots

- 2.9% (2) Brazos Pilots (Freeport, TX)
- 2.9% (2) Charleston Pilots
- 2.9% (2) Western Great Lakes Pilots
- 1.4% (1) Northeast Marine Pilots
- 1.4% (1) Galveston-Texas City Pilots

The units were used on the following bodies of water:

- Chesapeake Bay and Chesapeake and Delaware Canal
- Delaware Bay and Harbor, Chesapeake and Delaware Canal
- Houston Ship Channel, Galveston Bay
- Tampa Bay, Gulf of Mexico
- Corpus Christi Ship Canal/Laquine Channel
- Freeport Bay
- Charleston Harbor
- New York Harbor, Upper and Lower Bay, Arthur Kill North and South, Raritan Bay
- Long Island Sound, New Haven, Narragansett Bay, Providence, Fall River, Buzzards Bay, Cape Cod Canal, Boston Harbor
- St. Mary's River, Great Lakes

The units were used on a mix of both narrow rivers and open bays.

The pilots used the units on a total of 4,125 transits, with a range from 4-400 transits and a median of 30 transits. The Delaware Pilots had the most experience with the units: 2661 transits. Individually, they used units on an average of 148 transits. One pilot has used the unit on 400 transits, one on 350 transits, two on 300 transits, one on 200 transits, one on 196 transits, and two on 100 transits. By comparison, only two other pilots have used the unit on as many as 100 transits - one Maryland pilot on 200 transits and one Houston Pilot on 100 transits.

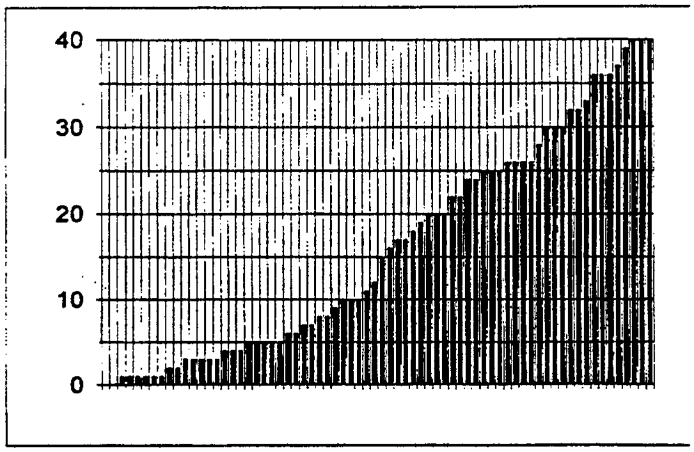
All together, the pilots who responded to the survey have 1,118 years of experience as pilots. They range in years of experience from 1-40 years, average 16.3 years of experience, and have a median of 26 years experience. The median is the better representation of the typical experience of pilots responding to the survey. The average is significantly lower than the median because 9 pilots have two years or less experience.

The pilots are tightly clustered in age, with 50% between 36 and 50 years old. They ranged from 25-66 years old, and averaged 44.7 years old.

The workload of the pilots averages 17.1 transits in an average month, with a range of 8-50 transits and a median of 15 transits. 62.4% of the vessels piloted by the surveying pilots are large, deep-draft vessels, 16.4% are small coasters, and 23.7% are other types.

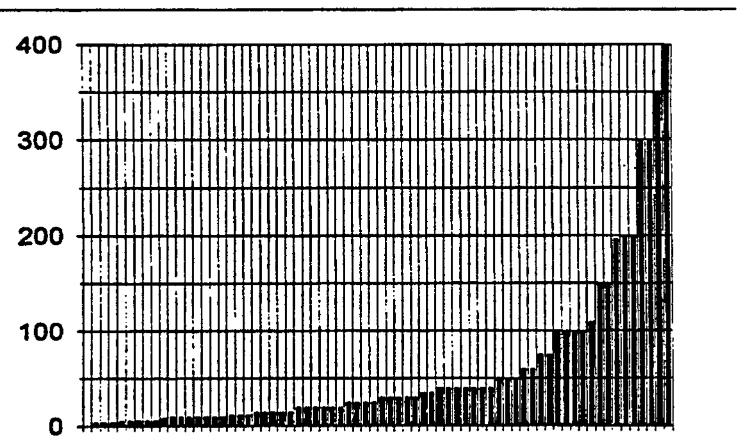
**Q51: How Many Years Have You Been A Pilot?**

| | |
|---|---|
| Total number of pilots: | 70 |
| Total Years: | 1,118 |
| Median Years: | 26 |
| Average : | 16.3 |
| Least Experience | 1 |
| Most Experience | 40 |




**Q44A: On How Many Transits Have You Used The Unit?**

| | |
|---|---|
| Total number of pilots: | 70 |
| Total Number of Transits: | 4,125 |
| Median Number of tranists: | 30 |
| Average number of transits: | 60.6 |
| Lowest number of transits: | 4 |
| Highest number of transits: | 400 |




The pilots used the following units in the evaluation:

77% (54) used the Raytheon Starlink unit.
14% (10) used the Hans unit.
4% (3) used the Cybernautix Navtrak unit.
3% (2) used the Ross unit.
2% (1) used the Astronautics Portable ECDIS unit.

## 6.4 FINDINGS: PHYSICAL CHARACTERISTICS AND OPERATION

- The total weight of the units with their carrying case ranged from 11-40 lbs., with a median of 22 lbs. and an average of 21.5 lbs; Without carrying case the units ranged 9-33 lbs., with a median of 14 lbs., and an average of 15.3 lbs. The Maryland pilots very consistently report 22 lbs with carrying case and 14 lbs without case. This finding is due to the fact that a Maryland pilot provided the data on the physical characteristics of the Ratheon/Starlink unit to the other Maryland pilots completing the evaluation. Responses of the other pilots vary quite a lot even for the same units.
- The average time required for unit setup once on the ship's bridge was 7.2 minutes, with a median of 5 minutes and a range of 2-18 minutes.
- The average time for unit breakdown and packing time for disembarking was 6.3 minutes, with a median of 5 minutes and a range of 2-16 minutes.
- The time required for the unit to display own ship position once turned on averaged 56.2 seconds, with a range from 20 - 240 seconds and a median of 30 seconds. 80% of the pilots report that it takes less than one minute to display ship's position, but a few report much longer delays:
  - 6 say 2 minutes, (1 from Great Lakes, 2 from Maryland and 3 from Delaware),
  - 3 say 3 minutes, (1 from Sandy Hook, and 2 from Delaware), and
  - 3 say 4 minutes (l from Maryland and 2 from Delaware). The Great Lakes pilot used an Astronautics system on an Acer Pentium Notebook. The others all used the Raytheon Starlink on a Toshiba 3400CT.
- In identifying the most difficult aspect of setting up the unit,
  - 22.4% of the pilots say finding an appropriate place to locate the antenna
  - 26.9% say stringing cable from the antenna to the unit
  - 28.4% say finding an appropriate shipboard power source
  - 7.5% say calibrating the unit or entering data at the start of the transit
  - 3.0% say other factors
  - 11.9% had no difficulties with set up
- A majority of evaluating pilots - 79% - consider their units durable enough to withstand the challenges of a marine environment in their port; 9% considered their units not durable enough; 12% had no opinion.

## 6.5 FINDINGS: OPERATIONAL CHARACTERISTICS

- The vast majority of the evaluating pilots (94%), felt it was easy to learn how to operate the unit; 3% said it was not easy. A majority of the evaluating pilots (78%), were comfortable using all of the different information capabilities of their units after some experience with them. 11% of the pilots were uncomfortable using all of the capabilities.
- 94.3% of the pilots report that they prefer to use ship's power for the unit's power source. This represents a combination of those who point out that the unit does not run on batteries, and those who say that even if it did, they would still prefer ship's power as more reliable. Other comments are that a battery would only add to the weight of the unit. One prefers to use the battery because on older vessels the ship's power supply is not always clearly marked and the voltage varies. Another pilot (using a Raytheon unit) would prefer to use batteries if he could because an appropriate shipboard power source is not always readily accessible to the DGPS unit location.
- 84% of the pilots felt that using the unit did not distract them from other traditional pilot duties.
- 98% of the pilots felt the unit provided a very high degree of accuracy of position and speed. 50% of the pilots state that at times information from the unit conflicted with information from the radar, of that 50%, 92% felt the unit was more accurate than ship's radar. 97% of the pilots state that at times information from the unit conflicted with information from the ship's Doppler speed log, of that 97%, 92% of the pilots felt the unit was more accurate than the ship's speed log. 84% of the pilots state that at times information from the unit conflicted with ship's gyro - of that 84%, 57% felt the ship's gyro was more accurate; 79% of the pilots state that at times information from the unit conflicted with the ship's ECDIS, of that 79%, 100% felt that the unit was more accurate than the ship's ECDIS. This finding that the portable unit provided more accurate information than the ship's ECDIS is due to the difference in quality of the electronic charts used by each system. The portable units generally utilize extremely accurate and port-customized digitized vector chart data, whereas many shipboard ECDIS units utilize generic raster and/or vector chart data of lesser accuracy.
- If the unit utilizes an icon for own ship, the majority of the evaluating pilots (69%) felt that having the ship's icon to scale is helpful; 17% had no opinion ; 14% felt it unhelpful.
- Some of the evaluating pilots are currently using the units for other purposes beside own ship navigational/position information, mostly to access tide and current information (41%), and to maintain trip logs/notes (23%).
- A majority of the evaluating pilots (61%), identify problems with reception due to structures.
- Virtually all of the pilots, (97%), indicate the unit clearly indicates to the pilot when the differential signal has been lost.

## 6.6 FINDINGS: ASSESSMENT & RELATED ISSUES

- When weighed against the inconvenience of use, 88% of the pilots consider the information provided by the units worth the effort of carrying them aboard and setting them up.
- 98% of the pilots feel the units enhance the safety of their piloting; 2% have no opinion; 0% feel the units do not enhance the safety of their piloting.
- 96% of the pilots feel the units have the potential to aid their piloting in terms of efficiency and safety.

- 81% of the pilots said using the unit encourages interaction with the ship's crew bridge team. 7% of the pilots said it discouraged their interaction with the ship's bridge team.
- 96% of the pilots would consider using the unit in restricted visibility; 96% of pilots would use it in fog; 96% in snow; 93% in rain. The occasions when some of the pilots (34%) would not the unit would be on short transits/shifts; 10% of the pilots would not use the unit in heavy traffic, 6% would not use it for narrow channel piloting, and 7% would not use it for precision anchoring.
- 70% of the pilots expressed concern about safety, operations, or liability if their pilot association did not establish a standard for software for the units in their association.
- 70% of the pilots expressed concern about safety, operations, or liability if their pilot association did not provide training in the use these units.
- The great majority of evaluating pilots (85%) would find it useful if their unit provided multi-ship information.
- A majority of evaluating pilots (69%) expressed concern about the crew and themselves tripping on the unit's cables.

## 6.7 FINDINGS: SELECTED OPEN END RESPONSES

*Q45: Overall, the features of the unit that I found to be most helpful were:*

1. Position

   "Immediate/real time position of ship in relation to center of the channel and depth of water"

   "Instantaneous position monitored for accuracy on a plotted database chart"

   "Course over the ground in narrow channels (i.e., set and drift)"

   "Cross-track error"

   "Almost pinpoint accuracy of position"

   "Position of vessel with respect to centerline of channel when meeting vessels in restricted waters"

   "Accurate cross track info on channels in vector mode"

   "Vector chart overlay is good if you need to go outside the channel, you can add buoys and notes onto the chart record of the trip."

   "Precise position of ship in all weather"

2. Course and Speed
   - "Nearly instant course and speed made good (without relying on ship's gear to provide this info)"
   - "Vessel location and speed over ground"
   - "Accurate speed"
   - "Course and distance to waypoints (turns, intersections, etc.)"
   - "ETA to final waypoint"

3. Information on hazards
   - "In fog and ice, also confirms locations of buoys when radar returns are weak and cluttered."
   - "Positioning of buoys in ice conditions"

- "Visibility of ice"
- "Warning of lost signals"
- "Beep alert to turn (waypoint)"

4. "Providing assurance that my skills in piloting are good " (26 years experience as a pilot).

5. "I had the opportunity to use the unit in 3 severe thunderstorms, one in which vessel's gyro failed and radar was poor. Unit performed impeccably and was not affected by lightning " (A Tampa pilot).

*Q46: My primary criticisms of the unit are:*

1. Over reliance is a risk.
   - "Too much reliance on unit and corresponding deterioration of other pilot skills"
   - "Two pilots following same course line in restricted visibility and having a collision"
2. Weight and bulkiness
   - "Unit very heavy to carry"
   - "Size, with all of its peripherals"
   - "Size and weight of the unit when boarding ship from pier while carrying other suitcase"
   - "DGPS unit should be changed into a 'tray' sort of unit that the laptop could snap into. The result: a smaller unit overall."
   - "Too bulky"
3. Set-up complications
   - "Set-up and take-down time"
   - "Playing with antenna wire"
   - "Difficult to setup due to wires involved and external power source"
   - "Antenna placement is too critical"
   - "Pain in the neck to board and disembark with due to size and weight"
4. Needs new features/modification of existing features
   - "Needs a rate of cross-track change"
   - "Too much technical data clutters screen"
   - "Install software to allow pilots to store data currently found in little black books"
   - "Charts that are scanned have too much info (e.g., LORAN lines, compass rose, etc). Chart software needs to be improved."
   - "Needs ship's gyro input"
   - "Needs ship's antenna input"

- "Screen is not bright enough in daylight"
- "Too much glare from screen"
- "Needs heading indicator"
- "Needs waterproof/shockproof/floatable case"

5. Loss of Information
   - "Loss of ship's icon at speeds below 5 knots"
   - "Inaccurate heading when turning"
   - "It gives course over ground of antenna, not of vessel, so you have to be aware of this"

*Q47: The greatest dangers that I feel exist with using such a unit in my piloting are:*

1. Over reliance
   - "Developing too great a trust/reliance on the system and subsequently doing something on a ship that I would not have done without the unit. Agents/owners are already asking us to move vessels under conditions where they should not."
   - "Relying solely upon the unit as an infallible source rather than viewing it as another tool that enhances your ability to do the job."
   - "Becoming too dependent on it and not relying on visual aids"
   - "Fixation on screen info and neglecting to look out the windows and use traditional info gathering, i.e., rudder angle indicator"
   - "Pilots not using other aids (radar and the master computer between their ears)"
   - "Forgetting that it is not radar and does NOT show other traffic"
   - "Not fully monitoring radar in poor visibility"
2. Loss of display
   - "Passing power plants and high power wires will lose signal."
   - "Loss of icon at speed less than 5 KT"
   - "Complacency, relying 100% on unit to have it lose the signal accuracy when I need it the most"
3. Safety
   - "Pilots will be pressured to proceed in ice and fog with only DGPS to aid them and then it fails."
   - "Not realizing when the unit is giving bad information"
   - "False sense of being the only vessel in the channel"
   - "Does not show other traffic"
   - "Pilots will not keep a good lookout."

- "Safety of pilots carrying such a heavy, cumbersome unit. The current unit is too big and heavy which compromises safety."
- "It's a distraction, only because it is so accurate. I spent much time looking at the screen instead of out the wheelhouse windows."
- "Closer meeting situations between vessels because distance off centerline information is so accurate"

*Q48: In order to improve the unit, I would suggest:*

1. Lighter and less bulky
   - "Lighter case"
   - "Smaller components, except for the PC screen"
2. Better display/visibility of keys
   - "Larger screen built on top of case"
   - "Backlighted keyboard or keypad with trackball or touchpad (with rheostat for light)"
   - "Ability to adjust screen brightness"
   - "Red screen for night use"
   - "Night use keys/Lighted keyboard"
   - "Add red overlay to reduce glare"
3. Less reliance on wire
   - "Retractable antenna cable and a/c extension cord"
   - "Wireless antenna, if one could be small enough and interference-resistant"
4. Better interface with ship
   - "Shipboard universal antennas"
   - "Add a feature to use ship's heading correction"
   - "Make the unit smaller (more portable) with a universal attachment to access the ship's own DGPS antenna"
   - "Gyro output or universal hookups for all vessels"
5. Other
   - "Better memory when switching from one program to another"
   - "Placing the antenna wire on a spring-loaded spool that is built into the carrying case"
   - "Deep water channel parameters (55 foot curve), wireless"
   - "Would show all targets with speed and distance"
   - "Enclose unit in hard, lightweight, floatable, watertight case at pilot association expense"

- "When the technology becomes affordable, place all the receiver functions (12 channel GPS, 2 channel differential) on a PCMCIA card. This will reduce weight and power supply needs greatly."
- "Add ECDIS charts for navigation areas"
- "Provide other vessel information"
- "Add heading indicator"
- "Set the unit up near the radar, NOT near the window, so both radar and DGPS can be viewed simultaneously"
- "Add a transponder"

*Q50: What training, if any, do you think pilots should receive in order to use the unit effectively?*

1. DGPS theory and operation of the unit
   - "A one-day course on the advantages and limitations of the unit, including how to operate it."
   - "A basic course in the presence of follow pilots with emphasis on the best functions of the unit that pertain to the area and types of vessels piloted"
   - "The operating parameters of DGPS and specific operational instruction on the software being used."
   - "Introduction to DGPS theory and development of DGPS. At least 2 days on technical theory, practical operation, and limitations of equipment"
2. Hands-on practice
   - "Classes in conjunction with use, under normal conditions, to improve confidence and speed in using it."
   - "Using the unit in good weather to familiarize with it"
   - "Using the system at low speeds and to make turns in the channel"
3. Theory and practice
   - "I believe that studying some GPS theory before receiving the unit is worthwhile, but then 'hands on' experience is the quickest way to become familiar."
   - "Ship simulator with DGPS interfaced to the exercisers, on board demonstration with DGPS experienced pilot and "classroom" type familiarization with issued unit."
   - "Extensive training including simulator and shipboard training with the unit the pilot will use"
   - "Test each pilot on use"

*Q27: Is there any other additional information that you would like the unit to provide or be utilized for?*

1. Tide and current information
   - "Real time tide, current, wind data (on screen)"
   - "Would like tide/current information with GAP data for bridges"

- "Real time tide information and interfaced with ship radar for other vessel positions"

2. Information on traffic
   - "Other ship navigational information via transponder"
   - "Vessel traffic system/location of other vessels using system"
   - "Eventually to be integrated with other pilots' DGPS receivers/transmitters"
   - "Accessing traffic report via modem"
   - "Port conditions, like real time tide data, weather, notices to mariners, urgent port information"

3. Other information
   - "Rate of cross-track change. Provide data for: rate this rate of change, how long before I'm back on centerline?"
   - "A glossary of wreck information of charts that are on my route."
   - "Gyro input, tide and current data (direction and speed)"
   - "DSC Marine information system, real time "ports"[14] information"
   - "Some type of variable ring to check distance, latitude, longitude, like on Raytheon unit in Philadelphia Pilot."
   - "True heading"

*Q28: Is there any information presented that you feel is not useful?*

- "ETA is presented, since speed is frequently changed. A better way would be to display total distance to go, so the pilot can estimate ETA."
- "Too much technical data on screen. I wish that info was available on another 'data info screen' rather than always displayed on the navigation screen."

[14] The Physical Oceanographic Real-Time System (PORTS) is a program of the National Ocean Service that supports safe and cost-efficient navigation by providing ship masters and pilots with accurate real-time information required to avoid groundings and collisions. PORTS includes centralized data acquisition and dissemination systems that provide real-time water levels, currents, and other oceanographic and meteorological data from bays and harbors to the maritime user community in a variety of user friendly formats, including telephone voice response and Internet - Ed.

## 6.8 EVALUATION CONCLUSIONS

1) The Portable Electronic Piloting Aid units enhance the safety of piloting.
2) The units provide very accurate position, speed, and chart information, in many cases more accurate than information provided by ship's equipment.
3) The units do not indicate heading with great accuracy, but do indicate course over ground (COG) with great accuracy.
4) The value and usefulness of the units is rated consistently high.
5) Use of the units does not distract the pilot from his traditional duties.
6) The units do not detract from bridge team interaction, but actually improve it.
7) The units are fairly easy to learn to use.
8) Decreasing overall weight is the most frequently cited means of improving the unit.
9) The great majority of evaluating pilots want their units to provide multi-ship information.
10) Wire cables required for unit operation present safety and operational concerns for many pilots.
11) If a ship icon is utilized in any of the unit's programs, it should be to scale.

**See Section 7.7 for Additional Conclusions.**

# 7
# CONCLUDING REMARKS

## 7.1 PEPA PROJECT OVERVIEW

At the time of this report, the reception of Portable Electronic Piloting Aid (PEPA) technology by U.S. piloting associations is varied. A couple of the larger U.S. pilot associations are currently fully committed to PEPA use in their normal operations. A number of other associations are considering and evaluating the technology for regular use in their ports. Many associations have adopted a "wait and see" approach to the technology, while still other associations question the utility of the technology for their ports altogether.

From a handful of different manufacturers, the PEPA units evaluated in this project were all manufactured in the last few years and similar in system design. They all utilize an off the shelf notebook computer linked to a GPS/DGPS receiver and portable antenna, and use U.S. Coast Guard or commercially broadcast Differential GPS signals to display own ship position on a very accurate electronic chart customized for the specific pilot association's body of water. They provide primarily own-ship navigational information, and provide it with an accuracy impressive to even the most skeptical and cautious of users. Indeed, the accuracy of the units is so impressive that over reliance on the units is frequently cited by pilots as the greatest risk in their use.

While it is clear that 70 U.S. pilots providing evaluations for the study (the majority of whom are from associations already committed to the technology) cannot and do not speak for all U.S. pilots, the fact is that the evaluating pilots are the pilots who have been exposed to working PEPA equipment on the water in actual piloting practice. They are in virtual unanimous agreement in reporting that PEPA technology enhances the safety of their piloting, and give these units very high marks for the accuracy of the information they provide. Although not without criticism and cautious words for the technology and its use, these pilots clearly indicate that PEPA equipment is a helpful tool which aids them in the day-to-day practice of piloting. The equipment provides the pilot with more and better information with which to make decisions, and increases overall confidence in the process, especially in adverse weather situations when other information-providing sources tend to break down (e.g., low visibility in fog, radar in squalls, etc.).

The application of this technology is quite clearly still in its infancy. The technology is advancing quickly. Wireless system components, multi-ship units connected via continuous communication links, improved battery and heading sensor capabilities, improved software features, and smaller sub-notebook, palm-sized equipment are all among developments likely to improve the performance and acceptance of PEPA systems in the near future.

As with the application of any new technology, there will be initial difficulties with PEPA use and development. U.S. pilots are already experiencing some of these difficulties now. Chart data issues, liability considerations, system dependability concerns, establishment of equipment standards, training requirements, and operating procedures are just some of the areas where attention is required now, and will be required in the future.

## 7.2 PRUDENT USE

Worth noting in an overall assessment of this technology is the fact that these own ship units are in their first years of use and do not as yet have an operational record over a period of years in the U.S. in any but a few specific locations; multi ship portable unit systems have virtually no operational record. The technology has not as yet proven its reliability and utility over a significant number of years in actual working piloting practice in numerous and varied applications.

In their most basic functions, these units require a number of properly working unrelated systems to support them, including electronic charting systems, DGPS, and laptop computer technology. The accuracy and reliability of any PEPA system is directly contingent upon these component technologies which support it. These supporting technologies bring their own strengths, characteristics, and limitations to the mix, and those strengths, characteristics, and limitations carry through to the performance of the end product, the information the pilot is receiving from the display screen. In the case of the pilot's carry aboard system, the whole is quite clearly not greater than the sum of its technological parts, but rather is *very directly limited by them.* To cite two obvious examples: 1) Irregularities in a differential beacon's signal transmission (poorly performing DGPS) carry through to the pilot looking at a correspondingly inaccurate picture of where his vessel in fact is; 2) Slightly inprecise digitized channel limit waypoints entered in the creation of a customized electronic chart carry through to the pilot viewing a correspondingly slightly imprecise display of how much water he may have to maneuver for an oncoming ship (with such an imprecision potentially magnified in proportion to the scale of chart being used).

Errors introduced in any of the supporting technology carry through to the end result. The bottom line is that at any given time, *a PEPA unit's positional information is only as accurate as the GPS and Differential signal's accuracy at that second, properly received and integrated by a receiver linked with a laptop computer's hardware and software, and displayed on an electronic chart with its own inherent accuracy.* It is quite possible that very accurate data from 90% of the system can be compromised by a poorly performing 10% of the system, e.g., a constellation of satellites and a differential signal yielding a 2 foot accuracy is severely compromised when displayed on a chart with a datum error of 8 meters, and can actually be quite dangerous to the pilot who thinks he's working with 2-3 meter accuracy and is in fact working in an 8 meter error condition. When combined in a multi-ship AIS/VTIS scenario, such errors introduced in the supporting technology would be retransmitted and affect the whole system.

In light of the above, it is important that this technology should never be used to substitute for or replace the traditional techniques of piloting, but rather should be used only to support them. When properly functioning and used with appropriate caution, PEPA units are best and most properly viewed as a helpful tool which can assist the pilot to safely do his job, providing him information which may aid in his decision making processes. To this end they show great promise; beyond this role they have the potential to do serious harm. Suggestions of these systems replacing channel buoys, of their being used by anyone other than properly trained and experienced pilots, or of their being used to move vessels in prohibitive weather conditions represent misconceptions of the proper role of this technology of potentially grave consequence. The phenomena known as "radar-assisted collision," which vigilant mariners strive constantly ~~on~~ TO guard against, applies equally well to all applications of PEPA technology.

What is unmistakably true is that much that will be learned as more pilots gain experience with these systems. As this experience is gained, the effect of these systems on piloting applications can be more thoroughly assessed.

## 7.3 ELECTRONIC CHART CONCERNS

In the critical area of the electronic charts which support these units, there is a marked range of quality in the charts manufacturers make available to the maritime public. The accuracy of any electronic vector chart is radically dependent upon the accuracy of the source data used to create the chart and the process by which that data is digitized. To the credit of virtually all of the U.S. piloting associations using or experimenting with this technology, only very high quality customized vector charts are being used for their PEPA units. These vector charts utilize the most accurate source data available, including U.S. Army Corps of Engineers channel and dredging data and National Oceanic and Atmospheric Administration (NOAA) and U.S. Coast Guard survey data. The accuracy of these custom made electronic charts is the primary reason why the PEPA units are in most cases more accurate than shipboard ECDIS systems, which do not maintain a comparably accurate electronic chart portfolio.

As pilot associations acquire units for their port, it is important that a common standard of chart data be utilized in that port. The need for this common standard is clear: It is essential for pilots in close quarters meeting, overtaking, and crossing situations to exchange information from the same electronic chart grids based on the same source data.

## 7.4 TRAINING

As PEPA systems are integrated electronic navigation systems which involve processing and displaying a myriad of data from numerous sources, their proper operation requires a knowledge and set of skills which has to be developed in untrained users. Users of PEPA units should possess, among other things, a solid understanding of DGPS and electronic charting, a working fluency with the unit's computer, a precise knowledge of the capabilities and limitations of their PEPA equipment, and a sound grasp of the techniques by which to incorporate the unit to advantage in working practice in a safe manner. To this end, pilot associations are to be encouraged in establishing systematic training programs by which their pilots will be both knowledgeable of, and comfortable with, their PEPA equipment before using it in practice. The Association of Maryland Pilots has a training program which is frequently cited as comprehensive and successful. (see Appendix C for a version of the Maryland DGPS Users Guide.)

Though not directly related to training, one area of PEPA application which should not be overlooked involves the maintenance of the individual PEPA units over time. The experience of U.S. associations currently utilizing PEPA systems indicates that a crucial function for reliable operation involves an ongoing maintenance program by which the accuracy and proper operation of the individual PEPA units are periodically verified. These associations established such programs early in their application of PEPA technology and consider them an essential ingredient for safe system operation.

## 7.5 MULTI SHIP

As stated previously, no area of PEPA technology is more under development than that of multi ship applications. Nor is there another of the technology area of the technology where pilots differ more strongly. While nearly all pilots rate very highly the ability to instantly and accurately confirm their position against other known sources and confirm other own-ship information, when discussing the topic of multi ship systems, opinions vary considerably. Some pilots want only own ship information and see nothing but trouble if the PEPA units are linked together. Other pilots want nothing less from the technology than a fully integrated port/vessel management system in which vessel position and information are but one small piece of a comprehensive port management tool, including live current and weather feeds, ship scheduling, cargo handling information, agent information, etc. (Two such comprehensive systems are presently being designed for installation in the port of LA/Long Beach and the Panama Canal.)

Partially responsible for this variance of opinion is the fact that consideration of multi ship applications immediately begs the question of VTS/VTIS/AIS[15] systems, and with that comes an array of frequently-debated issues which complicate the topic very quickly. The piloting ramifications of VTS/VTIS/AIS systems involve issues and concerns far outside the scope of this report, but it is important to point out that it is probable that the second evolution of PEPA technology will involve multi ship applications. As practical and cost effective communications solutions emerge by which individual PEPA units can be linked in a real time network, the issues related to VTS/VTIS/AIS systems will require attention.

## 7.6 PEPA TECHNOLOGY APPLICATION

Also worth noting is the sometimes overlooked fact that each port is unique - and each pilot association's operation is correspondingly unique. There is no one ideal PEPA system or application for all U.S. ports. Any application of PEPA technology in a given port is best evaluated and considered by the pilots of that port. Not only are pilots the prospective users of the technology, they are the population in the best position to determine how it might provide an enhancement to safety and efficiency of ship movement in their port.

Taken together, these last points suggest that the application of PEPA technology should not be rushed. The consideration of PEPA technology should proceed on a individual pilot association/individual port basis, without outside pressure from national or government entities. As individual associations utilize the technology, its strengths and weaknesses for specific applications will become clearer and better known, and this information can be shared with other associations. The experience and learning curve of all U.S. associations will progress together, and the profession as a whole will benefit as a result.

[15]Vessel Traffic Service/ Vessel Traffic Information Service/Automated Information System

## 7.7 ADDITIONAL CONCLUSIONS

In light of the analysis above in Sections 7.1 through 7.6, covering issues not fully addressed by the Evaluation data alone, the Vessel Piloting Cooperative Team drew the following Additional Conclusions:

12) As pilot associations acquire units for their port, it is important that a common standard of chart data be utilized in that port.

13) Portable Electronic Piloting Aid Units should never be used to substitute for or replace the traditional techniques of piloting, but rather be used only to support them.

14) Training in the proper use of the units and the technology they utilize is strongly encouraged.

15) For those pilot associations utilizing PEPA systems, an ongoing maintenance program should be established by which the accuracy and proper operation of the individual PEPA units are periodically verified.

16) Any application of PEPA technology in a given port is best evaluated and considered by the pilots and pilot association of that port.

17) The exchange of knowledge and experience with PEPA technology among U.S. piloting associations and PEPA system providers has enhanced safe ship piloting practice and should continue as the technology develops.

# REFERENCES


Ackroyd, N., and Lorimar, R., *Global Navigation - A GPS User's Guide 2nd Ed.*, Lloyd's of London Press, New York, NY. 1994.

Alexander, L. and Ganjon, F., *ECDIS: Current Status, Future Expectations,* Sea Technology March, 1995.

*Broadcast Standard for the USCG DGPS Navigation Service,* COMDTINST M1657 7.1, U.S. Coast Guard Headquarters, Washington, DC April, 1993.

Creamer, P., Alsip. D., and Radziszewski, J., *Performance Requirements for the Coast Guard's Differential GPS Service,* USCG Navigation Center, Navigation Information Service, Alexandria, VA.

*Federal Radionavigation Plan 1994,* U.S. Department of Defense, DOD-4650.5 and U.S. Department of Transportation, DOT-VNTSC-RSPA-95-1, Navigational Technical Information Service, Springfield, VA, May, 1995.

*Federal Radionavigation Plan 19942* U.S. Department of Defense, and U.S. Department of Transportation, Navigational Technical Information Service, Springfield, VA, January, 1993.

Gonin I., and Crowell, R., *Assessing Electronic Chart Systems,* USCG Research & Development Center, Groton, CT March, 1997.

*GPS Facts & Figures,* USCG Navigation Center, Navigation Information Service, Alexandria, VA, October, 1994.

Hall, G., and Schelechte, G., *USCG Differential GPS Navigation Service; Operational In 1996?*, USCG Navigation Center, Navigation Information Service, Alexandria, VA.

Hall, G., *USCG Differential GPS Navigation Service,* USCG Navigation Center, Navigation Information Service, Alexandria, VA.

Hurn, J., *DGPS Explained,* Trimble Navigation, Sunnyvale CA, 1993.

Hurn, J., *GPS A Guide to the Next Utility,* Trimble Navigation, Sunnyvale CA, 1989.

Kirchner, P., *Liability Considerations in the Use by Pilots of Their Own Carry-Aboard Navigation Equipment,* Presented to the International Maritime Pilots Association 13th Congress, May, 1996.

Langley, R., *The GPS User's Bookshelf,* GPS World, January, 1996.

Marine Board Committee on Advances in Navigation and Piloting, *Minding the Helm,* National Research Council, Washington, DC 1994.

Morrison, R., Association of Maryland State Pilots, *Maryland DGPS User's Guide for Maryland Pilot Program Ver. 3.0 and Starlink Wheelhouse Program Ver. 4.3,* Baltimore, MD 1995.

Pietrasewski, D., *Vessel Traffic Service (VTS) Digital Broadcasting,* Report No. CG-D-05-97, U.S. Coast Guard Research and Development Center, Groton, CT September, 1996. (available through National Technical Information Service, Springfield, VA).

Radio Technical Commission for Maritime Services (RTCM) Special Committee No. 104, *Recommended Standards for Differential Navstar GPS Service, Version 2.1,* Washington, DC January 1994.

Radio Technical Commission for Maritime Services (RTCM), *Annex 5, Draft Recommendation on Performance Standards for an Universal Shipborne Automatic Identification System (AIS),* RTCM Paper 94-97/SC101-178, IMO NAV Subcommittee 43rd Session Output Document, July 1997.

Rodriguez, M. and MacElrevey, D., Panama Canal Pilots/ Panama Canal Commission, *Vessel Communications and Traffic Management System Pilot Navigation and Communication Modernization Project*, Panama 1997.

Spalding, J., and Krammes, S., *Impact of USCG Differential GPS Service On User Equipment Technology,* Presented at the Institute of Navigation GPS-92 Conference, USCG Research & Development Center, Groton, CT, 1992.

Sytsma, D., *Applications of VHF-ELOS Technology for Automated Information Systems (AIS),* Kent, WA, April 1997.

U.S. Department of Commerce, National Technical Information Service Institute for Telecommunications Sciences, NTIS Special Publication 94-30,*A Technical Report to the Secretary of Transportation on a National Approach to Augmented GPS Services,* Boulder, CO, December 1994.

# CONTRIBUTORS

**Vincent Kirby** is an active Maritime Deck Officer and Independent Marine Consultant contracted by the Volpe National Transportation Systems Center in Cambridge, Massachusetts for the coordination and execution of this project.

**Wayne Baily and Joseph Bradley (Ret.)** are Marine Pilots of the Bay and River Delaware Pilots Association, Philadelphia, Pennsylvania.

**Carl Bowler** is a Marine Pilot of the San Francisco Bar Pilots and Chairman of the American Pilots Association's Navigation & Technology Committee.

**Joseph Frees** is an Independent Applied Research and Evaluation Specialist based in Melrose, Massachusetts, who provided evaluation expertise and guidance for this project.

**Frederick Ganjon** is the former Executive Director of the Office of Coast Survey, National Ocean Service, National Oceanic & Atmospheric Administration.

**James Maida** is a Technical and Product Development Consultant to ARINC in San Diego, California.

**Andrew McGovern** is a Marine Pilot of the Sandy Hook Pilot Association and Vice Chairman of the American Pilots Association's Navigation & Technology Committee.

**Richard Morrison** is a Marine Pilot of the Association of Maryland Pilots, Baltimore, Maryland, and a member of the American Pilots Association's Navigation & Technology Committee.

**Chuck Parker** is the Manager-New Business Development, Marine Sales and Service, of Raytheon Service Company, Mount Laurel, New Jersey.

**David Petrazewski** is the Acting Division Chief, Waterway & Marine Safety Technology Division, U.S. Coast Guard Research & Development Center, Groton, Connecticut.

**Larry Simpson** is a Field Applications Engineer with Ross Engineering, Largo, Florida.

**Donald Sytsma** is the President of Meteor Communications Corporation, Kent Washington.

**Brian Tahaney** is a Marine Pilot of the Tampa Bay Pilots in Tampa Florida.

**Daniel Waldeck** is a Marine Pilot of the Charleston Branch Pilots, Charleston, South Carolina.

**Joseph Warfield** is a Marine Pilot of the Houton Pilots and a member of the American Pilots Association's Navigation & Technology Committee.

**Colin Weeks** is the President of Hydrographic Associates, Houston, Texas.

**Donald Willecke** is a Marine Pilot of the Western Great Lakes Pilots Association, Superior, Wisconsin, and a member of the American Pilots Association's Navigation & Technology Committee

# APPENDIX A
# LIABILITY CONSIDERATIONS

**INTERNATIONAL MARITIME PILOTS ASSOCIATION**
**13TH CONGRESS**
**RIO DE JANEIRO, BRAZIL**
**May 30, 1996**

## LIABILITY CONSIDERATIONS IN THE USE BY PILOTS OF THEIR OWN CARRY-ABOARD NAVIGATION EQUIPMENT

Address By Paul G. Kirchner,
Executive Director - General Counsel,
American Pilots' Association

One of the more significant emerging developments in pilotage in the United States is the use by pilots of their own portable electronic navigation units - often referred to as portable piloting units PPUs). As this development has proceeded, pilots have expressed concern over the potential liability exposure associated with the use of these units. I am happy to share with you some of the thoughts and discussions we have had in the United States on this subject.

I will necessarily be limited to talking about United States law. The issues involved, however, should be similar under the law in most other places in the world where pilots operate, and the analyses that I will suggest are helpful in addressing these issues may also be helpful elsewhere. Ironically, the relevance of the discussion for this international audience may be heightened by the fact that, as we will discuss later, there is very little United States law that is specifically directed to this subject. If I cannot report to you specific answers, however, I can at least do what lawyers are more comfortable doing in any event: identifying issues and raising questions.

The talk will have three parts. First, we will discuss current United States pilotage law as it may govern the use, misuse, and non-use of portable piloting units. Second, we will run through several hypothetical accident scenarios involving PPUs. Many of these scenarios are taken from questions pilots have posed to me. Third, I will offer a number of common sense suggestions for minimizing the liability risks associated with PPUs.

**Background: Brief Description of PPUs**

There are a number of different types of PPUs currently being used or evaluated by U. S. pilots. Generally, the units are similar to laptop computers. In fact, in some cases, the PPUs are off-the-shelf laptops. A PPU is carried aboard by the pilot; set up on the bridge of the ship by the pilot; and then used by the pilot as a navigation information resource during the piloting assignment. The units provide, at a minimum, vessel positioning information utilizing the Differential Global Positioning System. The vessel's position is shown on an electronic chart-type display through software containing information specific to the particular pilotage area. In the future, PPUs may also provide positioning information for other vessels, either through a radar overlay/underlay or a link to a shoreside VTS center, as well as digital communication capabilities that would provide information such as real-time tide and current data.

At the present time, one group of U. S. pilots, the Philadelphia pilots operating on the Bay and River Delaware, has a PPU for each of its 70 pilots. The Maryland Pilots have 17 PPUs, which are used by pilots operating on the Chesapeake and Delaware Canal. In addition, the American Pilots' Association is currently engaged in a joint research and development project with the United States Maritime Administration to evaluate several of the presently available piloting units under actual piloting circumstances. A number of test ports have been selected, and a PPU has been provided for each test port. The units are being used now and evaluated by pilots. Evaluations will be collected through the end of the summer with the results analyzed and published in a report scheduled for release in early 1997. This is believed to be the first comparative assessment of commercially available PPUs under actual piloting conditions.

**Pilotage Law and the Use of PPUs: the Ideal**

Before we talk about what the current state of pilotage law relative to the use of PPUs, let me suggest what the law should be and how it should develop. Simply, the law should encourage, not discourage, the introduction of practices and technologies that will improve safety. Whether pilots should carry aboard and use their own electronic navigation units should be answered not by lawyers or judges but rather by pilots in the exercise of their own professional judgment.

To give a preview of my conclusion, I am optimistic that the law will match this ideal. In my opinion, pilots can and should proceed to make their own judgments as to the use of PPUs. So long as pilots exercise reasonable precautions, the potential liability exposure should not prove to be an insurmountable obstacle.

**PPUs and General Pilotage Law Negligence and Liability Principles**

There is usually a time lag between the introduction of new technology and practices and the development of a body of law or set of legal principles that would provide some relatively reliable guidance as to the use of such technology or practices and the resulting liability exposure for those who use them. This is because most of United States law consists of court or administrative decisions, and these occur only after a case or controversy arises. In the maritime field, this means only after an accident.

This is true with PPUs. The units and their use have simply not been around long enough for the development of a body of law that would provide the certainty that pilots, if not attorneys, would like to see. The unfortunate and unavoidable fact is that we will not see some specific guidance in this area until there is a major accident in which a PPU is an issue.

But this does not mean that pilots and their attorneys have to operate completely in the dark or that pilots should abandon their evaluation of PPUs. We can assess the potential liability risks by anticipating how the matter would be handled under traditional maritime law negligence and liability principles. We can also look to past cases that have involved the use of then-new technology, such as radar or ARPA, or pilot-supplied equipment, such as hand-held radios.

The basic description of pilot liability is that a pilot will be held responsible for his or her own negligence. This responsibility can take the form of a monetary judgment in a civil suit for injury or damages caused by the negligence; fines and penalties assessed by governmental regulatory bodies; loss or suspension of a license or reprimands by licensing authorities; or even criminal penalties in the event of gross negligence or willful misconduct, usually in connection with an oil spill.

In order to determine whether a pilot was negligent, the pilot's actions or behavior are compared to the standard of care to which the law holds the pilot. That is the standard of a reasonable and prudent pilot in light of the function and services the pilot is expected to provide. That is a high standard. [16]The law places a special duty on the pilot of a vessel based on his expertise and the responsibility he is charged with."' The pilot is presumed to possess superior local knowledge and advanced shiphandling and bridge management skills

On the other hand, a pilot is not a guarantor of the safe navigation of a vessel. A pilot is not responsible for acts of God, for unforeseen mechanical or equipment problems, or for the human errors of others. Even where an accident can be attributed to an action or decision of a pilot, liability is not imposed on the pilot unless the action or decision can be found to be contrary to what a reasonable, prudent pilot would have done under the circumstances. This aspect of a pilot's liability exposure has been described in a leading case on the subject as follows:

The duty of the pilot is to exercise that degree of care and skill possessed by the average pilot, and the mere fact that a different course of action might have avoided a collision is not enough in itself to condemn him to legal liability. The pilot's decision to handle the movement as he did was that of a reasonably competent harbor pilot under the circumstances that existed. He exercised the due care and skill required of him and was not required to be infallible. Furthermore, a navigator is not charged with negligence unless he makes a decision which nautical experience and good seamanship would condemn as unjustified at the time and under the circumstances shown[17].

As a practical matter, a pilot's performance is measured against this standard of care through the use of expert witnesses. The plaintiff or prosecution will hire an expert witness who will testify that the pilot did not do what a reasonably prudent pilot would have done under the circumstances. The defendant pilot's legal team will also have hired one or more expert witnesses who will testify that the pilot did what any other competent, excellent mariner would have done.

**Potential Liability Scenarios**

In each of the following scenarios, a ship accident has occurred, and a pilot's use or non-use of a PPU has been identified as a possible cause of the accident and as a possible grounds for imposing liability on the pilot.

1. Pilot Fails to Use Unit.

In this scenario, the pilot failed to use the PPU. He did not bring his unit aboard because he forgot it, or decided that it was too heavy to carry aboard, or just did not feel like using it. The pilot may have brought it aboard but never set it up. Or maybe he brought it aboard and set it up but then never looked at it during the period of time relevant to the accident.

---

[1]Transorient Navigators Co. S/A v. M.Southwind. 524 F.Supp. 373 (E.D. La. 1981); reversed on other grounds, 714 F. 2d 1358 (5th Cir. 1983); on remand, 609 F. Supp. 634 (E.D. La. 1985). The district court's decision on remand contains an additional description of the pilot's duty of care: "A river pilot is required to exercise a special and high degree of care in navigating waters through which he travels." Id. at 637.

[17] American Zinc Co. v. Foster, 313 F. Supp 671, 682 (S.D. Miss. 1970); modified, 441 F. 2d 1 too (5th Cir. 1971); cert denied, Ingalls Shipbuilding Div. Of Litton Systems. Inc. v. American Zinc Co., 404 U.S. 855 (Citations omitted). See also. Kingfisher Shipping Co., Ltd. V. M/V Klarendon, 651 F. Supp. 204, 207 (S.D. Tex. 1986): "A compulsory pilot's decisions are not negligent if they are the decisions a competent compulsory pilot might make under the same circumstances; thus, due care and skill is required of a compulsory pilot but not infallibility. (Citations omitted).

The basic issue in this scenario is whether there is a legal requirement that the unit be used. First, is there a governmental regulatory requirement that the unit be used? The answer to this question is particularly important under United States maritime law because the failure to use a unit in violation of a regulation requiring it invokes a presumption of fault. This is the so-called "Pennsylvania Rule," which gets its name from an 1874 decision by the United States Supreme Court involving the vessel PENNSYLVANIA.[18] In that case, the Supreme Court established the rule that if a ship or an individual involved in the navigation of the ship was acting in violation of a navigation safety regulation at the time of the accident, the ship or the individual is presumed to be negligent or at fault. At that point, the burden of proof shifts to the defendant - in our scenario, the pilot - to show that the violation could not have been a cause of the accident.

As far as I am aware, there is currently no regulatory requirement in the United States that a pilot use a PPU. It will not be too long before there is one, however. The first place where this will occur will not be federal or international requirements: both are still far in the future. Instead, in those states or ports where every pilot has a PPU, a state or local commission will eventually issue a regulation requiring the use of a unit for some or all pilotage operations. Most likely, this will occur where the pilots have been granted a specific adjustment to the pilot tariff to fund the acquisition and maintenance of the units. Typically, the pilots will have sold this tariff increase by arguing that the units are essential to providing the safest, and maybe even the most efficient, piloting services. The same thing has occurred in locations where pilots are required to carry cellular phones, the costs of which are covered in their rate base.

In addition, a number of PPU supporters envision that the units will eventually serve as the primary communication medium for a "silent" VTS system, with VTS-like information transmitted to the unit and displayed digitally on the screen. Once that happens in a mandatory VTS setting, it is logical to expect that there will be a regulatory requirement that every pilot carry aboard and use a PPU.

Second, even if there is no regulatory requirement for the use of a unit, there may be another basis for assessing liability in the case of a pilot's failure to use a unit. If using PPUs, especially in that particular pilotage area, has become so prevalent as to become an industry or professional standard, the failure to use a PPU could be considered a breach of the standard of care expected of pilots. This is a fact question that would be established by expert testimony. At the present time, with the exception of the Bay and River Delaware, there is no place that I know of where the use of PPUs is even approaching the level where it would be considered an industry or professional standard.

When it gets to that point, the issue may well be addressed in the same fashion as the use of hand-held radios was in the 1982 court decision, Texaco Trinidad. Inc. v. Afran Transport Co.[19] The case involved a casualty that occurred in 1979 when a loaded tanker struck an oil refinery's mooring buoy located off the coast of Trinidad. Texaco was the owner and operator of the refinery as well as the cargo owner of the oil in the tanker. Tankers were required by Texaco to use the services of a mooring team consisting of a pilot and at least two other individuals all of whom were employed by Texaco and supplied to the tankers. Texaco sued the owner of the ship for damages to the buoy.

The court ruled against Texaco on the ground that Texaco's own negligence was the cause of the accident. A principal factor in the accident was determined to have been the mooring team's

[18] The Pennsylvania, 86 U.S. (19 Wall) 125, 22 L.Ed. 148 (1873).
[19] 538 F. Supp. 1038 (E.D. Pa. 1982)

inability to communicate among themselves during the mooring maneuver. This inability was, in turn, attributed to the failure of Texaco to supply the pilot, its employee, with a portable radio. According to the decision, "it is customary and regular and normal procedure for the pilot to be furnished such a radio."[20] The same type of analysis would undoubtedly come into play with the non-use of a PPU. The question would be: is it "customary and regular and normal procedure" to use a PPU?

Third, even if an accident occurs in a pilotage area where PPUs are not use so much as to be a customary, regular, and normal procedure, that is not necessarily the end of the inquiry. Liability might still be imposed on the pilot if it could be shown that although the use of a PPU was not customary among pilots, the particular pilot involved had a unit available and did not use it under circumstances where if he had, the accident would have been prevented. There is a separate legal obligation to use available resources to avoid a collision. This is the basis, for example, of Rule 7 of the International and Inland Rules of the Road.[21] That rule requires each vessel to "use all available means appropriate to the prevailing circumstances and conditions to determine if risk of collision exists." A violation of Rule 7 would, of course, invoke the application of the Pennsylvania Rule. Even without a finding of a violation of Rule 7, however, testimony could be presented to establish that the use of an available unit would have been expected of a reasonable and prudent pilot under the circumstances.

There is an interesting case that demonstrates this aspect of liability. The case involved a 1987 allision of the tanker SEAPRIDE II with an electric transmission line tower in the Delaware River.[22] The ship was moving in ballast and in dense fog with near zero visibility. Although the ship was equipped with an ARPA, the A~A features were turned off at the time of the accident with the unit being used simply as a radar. It was shown at the trial that neither the pilot nor any of the ship's bridge crew, including the master, had been trained in the use of the ARPA. The court found, based on expert witness testimony from a Panama Canal pilot, that use of the ARPA would have prevented the accident. The defendants argued that the master and the pilot should be given wide discretion in their use of navigation aids. The court rejected that argument, however, concluding that the real reason why the ARPA was not used was because neither individual had sufficient training to do so.

Among the several findings of negligence made by the court against the ship was that both the pilot and the master violated Rule 2 of the Inland Rules of the Roads[23], which is the general negligence provision, because "an adequately trained seaman would have used [the ARPA] under the circumstances."[24] This finding called for the application of the Pennsylvania Rule with the court concluding that the ship could not rebut the presumption of fault because it could not show that the failure to use the ARPA could not have been a cause of the accident.

The training issue will addressed in our discussion of the next scenario. The significance of the SEAPRIDE II case for this scenario is that it demonstrates that although there was, and is, no specific regulatory requirement that an ARPA be used (nor, for that matter was there a regulatory requirement that the master or pilot be trained in the use of an ARPA), the failure to use that available resource under the circumstances was found to be negligence.

2. Pilot Makes Mistake in the Use of the Unit.

---

[20] Id. At 1041.
[21] 33 U.S.C. foll. §1062; 33 U.S.C. §2007 (Inland Rule).
[22] In Re Waterstand Marine, Ltd., 1991 AMC 1784 (E.D. Pa. 1988).
[23] 33 U.S.C. §2002.
[24] Supra at 1799.

In this scenario, the pilot brought his unit aboard. He might not have set it up correctly, however, or did not place the antenna where it should have been, or punched the wrong buttons. Whatever the reason, his actions caused information from the unit, information upon which he relied, to be inaccurate. Alternatively, the unit may have been operating properly and providing accurate information, but the pilot misread or misinterpreted the information.

Because this scenario assumes that the pilot made a mistake and that his mistake was a cause of the accident, the potential for pilot liability is understandably high, as it would be under traditional pilotage law liability and negligence principles. As we discussed earlier, however, not every mistake or error of judgment constitutes negligence. As a practical matter, the pilot would have to show that his error or mistake could have been made by any competent pilot acting with reasonable care. Obviously, this would be a heavy burden.

It can be expected that one of the first areas of inquiry will be the pilot's training in the use of the unit. Although the SEAPRIDE II case was primarily about the failure to use an available piece of navigation technology, the analysis in the case of the training issue gives some indication of how this would be handled in our scenario.

The SEAPRIDE II court specifically found that providing the ship's crew with an instruction manual was not sufficient. In the process, it suggested, as have other cases, that the more advanced and complex a technology is, the higher the degree of training that would be expected of our ideal "reasonable and prudent pilot." This seems to be a matter of common sense and would presumably apply with special force in the use of portable computer equipment by individuals who, in many cases, would not have had extensive training or familiarity with computers.

3. Pilot Fails to Maintain Unit.

In this scenario, an accident occurs when a PPU fails to work or works improperly and the problem was caused by the pilot's failure to maintain the unit. The pilot may have failed to keep the batteries charged, in the case of a unit that uses battery power. For a unit that uses the ship's power, the pilot might have forgotten or lost the power cord. The pilot may have filed to keep the software updated or otherwise failed to keep the unit in good working order.

Again, the issue is the standard of care expected of our reasonable prudent pilot in the upkeep of the pilot's unit. An expert witness might well testify that it is usual and customary to: a) carry extra batteries, power cords and other ancillary equipment, b) have regular, periodic maintenance checks, or c) make arrangements to insure that software is updated. These types of expectations are similar to what pilots have faced for years with their handheld radios. The Texaco case we discussed previously, in fact, provides a good example of how this issue has been treated with radios.

In that case, even though the court found Texaco liable for failing to provide its pilot with a radio, which is the normal and customary practice, the court further observed that "it is customary for the radio to be tested before the pilot leaves shore and takes his position on the ship to undertake piloting operations."[25] This suggests that the court would have found Texaco and its pilot at fault even if the circumstances of the accident had been that the inability of the mooring team to communicate had been caused not by the failure of the pilot to take a radio aboard but rather by a failure of the radio to work when it was needed.

[25] Supra.

4. Pilot or Pilot Association Is the Source of Erroneous Information or Is the Manufacturer/Developer of a Defective Unit or Software

In some places, pilots or their pilot associations are contracting with programmers to develop navigation software that becomes proprietary to the pilots. In other places, and more typically, pilots provide information to unit manufacturers or software developers in order to "fine tune" or verify the accuracy of the information. The resulting unit and software remains the product of the manufacturer, who may be free to sell it to other users. Finally, many pilots want to "customize" their units with their own information or with features that they find particularly useful.

What happens if, under any one of these variations, erroneous information or a defect in the unit that causes an accident can be attributed to the information provided by the pilots or deemed to be the property of the pilot or pilot association? There may well be some liability exposure here. This moves us beyond the usual components of traditional pilotage law into areas such as product liability and programmer's liability in computer law.

A key here will be the contractual arrangements between the pilot or pilot association and the software developer or unit manufacturer/vendor. Under the contract, who is responsible for defects in software or hardware? Is the pilot or pilot association indemnified against claims from third parties arising out of accidents caused by defects in the unit or software, even defects due to erroneous information supplied by pilots? The indemnification question looms particularly large if a manufacturer sells a unit or its pilot-perfected software to other users, who could in turn come back against
the manufacturer and the pilots who contributed, perhaps, the error in the unit or its information.

Unfortunately, I can offer even less specific guidance on these issues than on the issues raised in the other scenarios. The liability of the manufacturers and developers of navigation technology and electronic navigation software is itself a developing area of the law combining maritime law and computer/intellectual property law. It is well beyond the scope of this brief discussion today. Extensive, multi-day conferences on the subject, such as "Maritime Law and ECDIS" in New Orleans in March of 1995, have been held recently with intensely debated speculations on what legal principals will eventually emerge from the introduction of new navigation information resources and technology. Pilots who participate in this development will also share in the potential legal uncertainties.

5. Pilot Does Nothing Wrong.

What is the pilot's exposure if a PPU malfunction causes an accident, and the pilot can show that he did everything right? The pilot brings the unit aboard, sets it up properly, consults it at appropriate times during the piloting job, and practices good prudent piloting. A defect in the unit or inaccurate information, on which the pilot reasonably relies, however, causes an accident.

Although I have saved this scenario for last, it is probably the one that makes pilots most uncomfortable and is the most frequent question I hear on the PPU liability subject. Pilots, at least those in the United States, have always worked with the knowledge that they may be held liable for their own negligence. If they fail to perform their services in the manner of a reasonably prudent pilot, they may have a problem. On the other hand, if they rely on equipment onboard a ship that causes an accident, and if they can show that the reliance was reasonable and that they otherwise did everything right, they can walk away leaving it to the shipowner and the equipment manufacturer to fight over who is ultimately liable. A malfunctioning PPU is different, however. When a pilot provides the equipment, what is his responsibility for it?

The initial question would be whether the use of a PPU is sufficiently accepted as a reasonable and safe practice in the profession. The answer to that question would largely be a matter of how prevalent the use of the units is among pilots. This issue will, of course, lessen as a potential risk feature as the use of the units increases. Meanwhile, we should be aware of the likely argument that this technology and practice is too experimental and unproven for its use to be reasonable and prudent. Again, this would be a battle of the expert witnesses.

The next likely issue would be the reasonableness of the pilot's reliance on the information from the unit. If the use of the unit and its information is found to be an acceptable practice, can the pilot escape liability by showing that he relied on information from the unit, which subsequently was found to be inaccurate? There are, of course, many cases in U.S. law governing pilots' reliance on navigation aids - buoys, charts, shipboard equipment, etc. The rule that seems to emerge from these cases calls for a review of all the circumstances to determine whether the reliance was reasonable. A case involving reliance on information from a PPU would probably examine what, if any, other sources of information were available to the pilot. Also, would a reasonably prudent pilot's local knowledge and shiphandling and BRM skills have overcome the inaccuracy of the unit's information? Assuming that a pilot is not responsible for the inaccuracy of the information, the pilot's liability situation should be much the same as it would in the case of reliance on shipboard equipment.

I am not aware of any legal principles under U. S. maritime law that would put the pilot in the position of a guarantor of pilot supplied equipment, where the pilot would have liability similar to strict liability or product liability in the absence of negligence or other fault. Negligence will still be the liability standard. The pilot's actions will be measured against the standard of the reasonable, prudent pilot under similar circumstances.

## Practical Suggestions for Minimizing Liability Exposure

1. If unit is taken aboard, set it up and use it. Members of the bridge crew who see a pilot bring aboard a unit and then leave it with his coat and bag somewhere in the back of the bridge will likely point that fact out to investigators in event that the ship has an accident. This will draw attention to the pilot's failure to use a PPU and perhaps raise an issue that otherwise might not have been raised. The burden would then be on the pilot to justify the decision not to use an available resource and to show that the use of the unit would not have prevented the accident.

2. Learn as much as possible about PPUs. Talks to pilots in other groups and locations who use PPUs, and talk about them within your own group. In the event of an accident, a pilot should be able to talk credibly about the use, benefits and limitations of the units. The SEAPRIDE II case demonstrates that a court may be reluctant to give a pilot discretion in decisions on the use of technology and to respect the pilot's professional judgment when it appears that the pilot may not know what he or she is talking about.

3. Receive training before using a unit. Clearly, liability risks are enhanced when a pilot, particularly an older pilot without significant familiarity with computers and electronic information systems, is simply handed a PPU and dispatched to a ship. Most unit vendors offer training courses, and schools in the United States offer courses in the use and operations of PPU. These school courses reflect the two types of training available for PPUs. One is training in the operation of the PPU, and the other is bridge management training that focuses on how pilots should incorporate the PPUs into their pilotage operations. Both types of training have real value.

4. Continue to exercise good piloting practices. Some pilots have told me that they are concerned about becoming overly fascinated with the unit to the exclusion of other sources of information and communication with the bridge crew. Remember that a PPU is only one navigation aid or bridge resource.

5. Always carry spare batteries, power cords, and other ancillary equipment.

6. Establish a system for periodic maintenance checks. At least one pilot group has entered into a contract with the unit manufacturer to have a technician come on a regularly scheduled basis to test units and to update software as needed. Keep a log of maintenance checks and software updates.

7. If proprietary or customized unit is developed, include liability protection provisions in the contract with the developer or programmer.

8. If pilots are asked to provide information or to verify software data, get prior agreement on liability protection.

9. In locations where the pilots are covered by a liability limitation statute, check the language of the statute to insure that use of a PPU would be considered within the activities for which liability is limited.

10. Try not to overpromote PPUs. In their zeal for advancing the use of PPUs or for obtaining funding through the pilotage rates for PPUs, some pilots may tend to exaggerate the benefits of PPUs in the prevention of accidents. This might have the effect of raising expectations to the unreasonable level where the fact that an accident occurs when a pilot is using a PPU will create a presumption that the pilot had to have been negligent in some way.

## Conclusion

Where does this leave us? It leaves us where I think pilots have always been. The best protection against liability is to do the best piloting job you can. Not only will that prevent accidents, it will put the pilot in the best legal position in case an accident does occur.

The U. S. Pilots here have heard me say what I am going to say many times before. With apologies to them, let me offer a piece of advice: pilots should avoid trying to think like lawyers. Many of the most serious legal problems that I see pilots get themselves into happened when they made a decision on the bridge of a ship, often under emergency circumstances, by trying to recall what they think they heard a lawyer say or, even more dangerous, trying to themselves speculate what a lawyer would do under the circumstances.

Don't do this! BE A PILOT! Fall back on your training and instincts and keep in mind why you are on the bridge of a ship. It is becoming increasingly clear that a pilot's job, and what the public and the law expects of a pilot, is to prevent an accident. Do whatever you can, and use whatever resources are available, to prevent an accident. If an accident does occur, I am convinced that the law favors those who can show that they did their best rather than those who tried to avoid liability.

If using a portable, carry-aboard piloting unit will, in the pilot's own professional judgment, help to prevent an accident and will genuinely enhance safety and improve the pilot's performance, the pilot should use it. I believe a pilot can do so under current United States law without exposing himself or herself to significantly greater liability risks. The key is to be prudent and to exercise some common sense measures to limit the liability exposure.

# APPENDIX B

# EVALUATION DATA: SELECTED CLOSED ITEM RESPONSES

## PHYSICAL CHARACTERISTICS & OPERATION

Q13. Please indicate whether you strongly agree, agree, have no opinion, disagree, or strongly disagree with each of the following statements.

- Transporting the unit to/from a ship was difficult

15.7% Strongly agree
35.7% Agree
10.0% No Opinion
34.3% Disagree
4.3% Strongly Disagree

- Finding a safe location in the wheelhouse was difficult

1.4% Strongly agree
15.7% Agree
12.9% No Opinion
58.6% Disagree
11.4% Strongly Disagree

- Finding an appropriate location for the DGPS antenna was easy

11.4% Strongly agree
52.9% Agree
10.0% No Opinion
24.3% Disagree
1.4% Strongly Disagree

- Locating an available on-board power source was easy.

2.9% Strongly agree
51.4% Agree
5.7% No Opinion
38.6% Disagree
1.4% Strongly Disagree

- Connecting all of the cables and components necessary for the unit was difficult

0 % Strongly agree
11.4% Agree
11.4% No Opinion
67.2% Disagree

10.0% Strongly Disagree

- Transporting the unit as I boarded and left was easy and safe.

| | |
|---|---|
| 7.2% | Strongly agree |
| 40.6% | Agree |
| 8.7% | No Opinion |
| 34.8% | Disagree |
| 8.7% | Strongly Disagree |

- I was concerned about the crew and myself tripping on the power supply and antenna cables of the unit.

| | |
|---|---|
| 11.4% | Strongly agree |
| 57.2% | Agree |
| 10.0% | No Opinion |
| 20.0% | Disagree |
| 1.4% | Strongly Disagree |

- The weight of the entire carry-on package was too much for me to routinely carry on-board for all of my jobs.

| | |
|---|---|
| 11.4% | Strongly agree |
| 18.6% | Agree |
| 10.0% | No Opinion |
| 51.4% | Disagree |
| 8.6% | Strongly Disagree |

- Carrying the extra weight of the battery is worth the convenience of not having to use ship's power.

| | |
|---|---|
| 0% | Strongly agree |
| 10.2% | Agree |
| 42.4% | No Opinion |
| 33.8% | Disagree |
| 13.6% | Strongly Disagree |

- During set-up lime. I was not able to give my attention to other concerns I felt needed to be addressed.

| | |
|---|---|
| 5.7% | Strongly agree |
| 40.0% | Agree |
| 8.6% | No Opinion |
| 41.4% | Disagree |
| 4.3% | Strongly Disagree |

- The size of the carry-on bag was easy to manage.

| | |
|---|---|
| 5.8% | Strongly agree |
| 42.1% | Agree |
| 13.0% | No Opinion |

30.4% Disagree
8.7% Strongly Disagree

- The unit is not durable enough to withstand the challenges of a marine environment in the port where I work.

1.4% Strongly agree
7.1% Agree
12.9% No Opinion
57.2% Disagree
21.4% Strongly Disagree

Q14. Does your unit clearly indicate when it has lost the differential signal?

97.1% Yes
2.9% No

Q15. Does your unit clearly tell you if the integrity monitoring system at the beacon is not working properly?

23.9% Yes
62.7% No
13.4% Don't know

Q16. Does your unit rate the health of the satellite signals?

74.6% Yes
20.9% No
4.5% Don't know

Q18. Does your unit 's differential hardware have a dual receiver that receives one beacon signal while it constantly looks for a better signal?

82.1% Yes
3.0% No
14.9% Don't know

Q19. Can the software controlling your DGPS be set to search for only the frequencies of selected beacons in your urea?

83.8% Yes
4.4% No
11.8% Don't know

Q20. Does your unit have any problems with reception due to:

Distance

15.3% Yes
84.7% No

Weather

18.6% Yes
81.4% No

Structures

61.0% Yes
39.0% No

Other Users

100% No

Ship's Equipment

8.5% Yes
91.5% No

No Problems Encountered

32.8%

Q26. Does your unit have an open architecture so that future software programs can be easily added to the unit?

91.3% Yes
8.7% Don't know

## PRESENTATION OF INFORMATION

Q24. In addition to own-ship navigational information, does your unit provide navigational information on other ships (i.e., does it have multi-ship capability)?

4.3% Yes
95.7% No

- Would you find it useful if the unit provided such information?

84.8% Yes
15.2% No

Q25. Beside own-ship navigational/position information (and other-ship navigational information, if provided), do you use your unit for any of the following other uses?

- Accessing tide/current information

41.4% Yes
58.6% No

– Maintaining trip log/notes

| | |
|---|---|
| 23.1% | Yes |
| 76.9% | No |

– Billing

| | |
|---|---|
| 100% | No |

Q29. Is your display screen:

| | |
|---|---|
| 0 % | Monochrome (black and white) |
| 13.8% | Dual scan color |
| 86.2% | Active matrix color |

Q30. Can you control the intensity of the display at night to reduce glare from the screen?

| | |
|---|---|
| 95.6% | Yes |
| 4.4% | No |

Q31. Please indicate whether you strongly agree, agree, have no opinion, disagree, or strongly disagree with each of the following statements:

– It was easy to learn how to operate the unit.

| | |
|---|---|
| 41.8% | Strongly agree |
| 52.2% | Agree |
| 3.0% | No opinion |
| 3.0% | Disagree |
| 0% | Strongly disagree |

– The function keys needed to operate the program are easy to remember and use.

| | |
|---|---|
| 29.4% | Strongly agree |
| 54.4% | Agree |
| 11.8% | No opinion |
| 2.9% | Disagree |
| 1.5% | Strongly disagree |

– The screen display provides useful information.

| | |
|---|---|
| 50.0% | Strongly agree |
| 48.6% | Agree |
| 1.4% | No opinion |
| 0 % | Disagree |
| 0 % | Strongly disagree |

– The pull-down menus or different screens are too hard to use.

| | |
|---|---|
| 0 % | Strongly agree |

| | |
|---|---|
| 4.3% | Agree |
| 27.5% | No opinion |
| 50.8% | Disagree |
| 17.4% | Strongly disagree |

- Using the mouse/trackball/joystick (if equipped) is easier than using the keyboard functions.

| | |
|---|---|
| 11.6% | Strongly agree |
| 34.8% | Agree |
| 33.4% | No opinion |
| 18.8% | Disagree |
| 1.4% | Strongly disagree |

- The keyboard is too hard to see at night.

| | |
|---|---|
| 17.1% | Strongly agree |
| 47.2% | Agree |
| 7.1% | No opinion |
| 25.7% | Disagree |
| 2.9% | Strongly disagree |

- It is easy to locate the function keys in the dark.

| | |
|---|---|
| 1.5% | Strongly agree |
| 25.0% | Agree |
| 8.8% | No opinion |
| 48.5% | Disagree |
| 16.2% | Strongly disagree |

- The screen is easy to read in bright sunlight on a bridge with a lot of windows.

| | |
|---|---|
| 5.9% | Strongly agree |
| 52.9% | Agree |
| 4.4% | No opinion |
| 29.4% | Disagree |
| 7.4% | Strongly disagree |

- The screen is too bright at night.

| | |
|---|---|
| 4.3% | Strongly agree |
| 31.9% | Agree |
| 4.3% | No opinion |
| 52.3% | Disagree |
| 7.2% | Strongly disagree |

- The presentation can be adjusted to either increase or decrease the scale of the channel.

| | |
|---|---|
| 33.8% | Strongly agree |
| 61.8% | Agree |

| | |
|---|---|
| 0 % | No opinion |
| 2.9% | Disagree |
| 1.5% | Strongly disagree |

- Having the ship's icon to scale is not helpful.

| | |
|---|---|
| 0 % | Strongly agree |
| 14.3% | Agree |
| 17.1% | No opinion |
| 41.4% | Disagree |
| 27.1% | Strongly disagree |

- The screen size is too small to adequately display information.

| | |
|---|---|
| 2.9% | Strongly agree |
| 4.3% | Agree |
| 7.1% | No opinion |
| 64.3% | Disagree |
| 21.4% | Strongly disagree |

- Even after some experience with the unit I am still not comfortable using all of its different information capabilities.

| | |
|---|---|
| 1.4% | Strongly agree |
| 10.0% | Agree |
| 10.0% | No opinion |
| 54.3% | Disagree |
| 24.3% | Strongly disagree |

## ACCURACY OF THE INFORMATION PROVIDED

Q32. When in use, what percentage of the time is the

- DGPS-indicated position accurate?

| | |
|---|---|
| Range: | 85-100% |
| Median: | 98% |

- DGPS-indicated speed accurate?

| | |
|---|---|
| Range: | 88-100% |
| Median: | 98% |

Q33. Do you notice any positional inaccuracies induced by the location of the antenna in relation to the ship 's pivot point?

| | |
|---|---|
| 35.2% | Yes |
| 64.8% | No |

– the unit 's method of correcting for antenna location?

14.5% Yes
85.5% No

Q35. Do you have to manually log in initial heading in order to get the unit to function properly?

4.8% Yes
95.2% No

Q36. Does the accuracy of the ship 's heading information vary with any of these factors?

– Speed

26.2% Yes
73.8% No

– Interfering structures

21.0% Yes
79.0% No

– Proximity to other users

1.6% Yes
98.4% No

– Ship 's equipment interface

3.2% Yes
96.8% No

Q37. Does the information from the unit ever conflict with information from the following sources? If it does, which information seems to be the most accurate?

– Conflict with radar
50.0% unit never conflicts
50.0% unit does conflict

Which is more accurate?
92.0% Unit
8.0% Radar

– Conflict with Doppler Speed Log?
4.5% unit never conflicts
96.5% unit does conflict

Which is more accurate?
92.2% Unit

7.8% Doppler

- Conflict with Ship 's gyro?
  16.4% unit never conflicts
  83.6% unit does conflict

  Which is more accurate?
  42.9% Unit
  57.1% Gyro

- Conflict with ECDIS?
  20.8% unit never conflicts
  79.2% unit does conflict

  Which is more accurate?
  100% unit is more accurate
  0% ECDIS is more accurate

## THE UNIT IN USE

Q.38 Would you not use the use the unit in any of these conditions?

4.3% would not use in restricted visibility
7.1% would not use in rain squalls
4.3% would not use in fog
4.3% would not use in snow
10.0 % would not use in heavy traffic
4.3% would not use on long transits
34.3% would not use on short transits/shifts
5.7% would not use in narrow channel piloting
7.1% would not use in precision anchoring

Q40. Please indicate whether you strongly agree, agree, have no opinion, disagree, or strongly disagree with each of the following statements:

- Using the unit distracts me from other traditional pilot duties.

| | |
|---|---|
| 0 % | Strongly agree |
| 15.7% | Agree |
| 10.0% | No opinion |
| 61.4% | Disagree |
| 12.9% | Strongly disagree |

- Using the unit discourages my interaction with the ship's crew bridge team.

| | |
|---|---|
| 0 % | Strongly agree |
| 7.2% | Agree |
| 11.6% | No opinion |
| 65.3% | Disagree |

15.9% Strongly disagree

- I do not use the unit during periods of restricted visibility.

| | |
|---|---|
| 0 % | Strongly agree |
| 0 % | Agree |
| 2.9% | No opinion |
| 47.8% | Disagree |
| 49.3% | Strongly disagree |

- I only use radar during periods of restricted visibility.

| | |
|---|---|
| 0 % | Strongly agree |
| 2.9% | Agree |
| 2.9% | No opinion |
| 56.5% | Disagree |
| 37.7% | Strongly disagree |

- While anchoring in good weather, I rely heavily on the unit.

| | |
|---|---|
| 0 % | Strongly agree |
| 20.3% | Agree |
| 23.2% | No opinion |
| 49.3% | Disagree |
| 7.2% | Strongly disagree |

- During significant course changes, I rely mostly on traditional aids to navigation or landmarks to adjust the swing of the vessel.

| | |
|---|---|
| 37.1% | Strongly agree |
| 58.6% | Agree |
| 0 % | No opinion |
| 4.3% | Disagree |
| 0 % | Strongly disagree |

- I use the unit while docking and undocking.

| | |
|---|---|
| 0 % | Strongly agree |
| 8.6% | Agree |
| 21.4% | No opinion |
| 42.9% | Disagree |
| 27.1% | Strongly disagree |

- The ship 's speed log is more accurate than the DGPS speed.

| | |
|---|---|
| 1.4% | Strongly agree |
| 2.9% | Agree |
| 8.7% | No opinion |
| 44.9% | Disagree |
| 42.0% | Strongly disagree |

- During periods of restricted visibility I use the unit in conjunction with radar.

| | |
|---|---|
| 62.3% | Strongly agree |
| 37.8% | Agree |
| 0 % | No opinion |
| 0 % | Disagree |
| 0 % | Strongly disagree |

Q41. Would you have any concerns about safety operations, or liability in any of these conditions?

- If only some of the pilots in your port used these units?

| | |
|---|---|
| 30.0% | Yes |
| 70.0% | No |

- If pilots were able to customize their units with individual information (e.g., add waypoints)?

| | |
|---|---|
| 38.6% | Yes |
| 61.4% | No |

- If the pilots association did not establish a standard for software to be used in your port?

| | |
|---|---|
| 75.7% | Yes |
| 24.3% | No |

- If each pilot had to purchase his own unit?

| | |
|---|---|
| 38.6% | Yes |
| 61.4% | No |

- If the pilots association did not provide training on these units?

| | |
|---|---|
| 70.0% | Yes |
| 30.0% | No |

Q42. Did your unit come with an instruction manual or user's guide?

| | |
|---|---|
| 97.1% | Yes |
| 2.9% | No |

- Was it written in a way that was easy or a pilot to understand?

| | |
|---|---|
| 95.6% | Yes |
| 3.4% | No |

Q43. Please indicate whether you strongly agree, agree, have no opinion, disagree, or strongly disagree with each of the following statements?

– I think the unit does not enhance the safety of my piloting.

| | |
|---|---|
| 0 % | Strongly agree |
| 0 % | Agree |
| 2.8% | No opinion |
| 44.3% | Disagree |
| 52.9% | Strongly disagree |

– The unit does not have the potential to become a useful tool which will aid my piloting in terms of safety.

| | |
|---|---|
| 1.4% | Strongly agree |
| 2.9% | Agree |
| 0 % | No opinion |
| 34.3% | Disagree |
| 61.4% | Strongly disagree |

– The unit has the potential to become a useful tool which will aid my piloting in terms of efficiency.

| | |
|---|---|
| 60.1% | Strongly agree |
| 37.1% | Agree |
| 1.4% | No opinion |
| 1.4% | Disagree |
| 0 % | Strongly disagree |

# Maryland DGPS User's Guide

## for Maryland Pilot Program Version 3.0

## and Starlink's Wheelhouse Program Ver. 4.3

by Dick Morrison

**DISCLAIMER**

**This User's Guide is not for public distribution. If it is used in any form the user takes all liability for its use. Dick Morrison and the Association of Maryland Pilots do not guarantee the accuracy or correctness of this guide - USER BEWARE –**

**This guide is my understanding of the Starlink navigation program. It is not guaranteed to be correct on every aspect of the program's operation even though I am endeavoring to make it so. The program is continually being modified and improved. This guide is for version 3.0 . Where will be updates as changes are made to the program. The following people have been of great assistance to me on this GPS project: David Fowler and Jim Ritchie of Starlink Incorporated, Chuck Parker of Raytheon Service Company and Joseph Bradley of The Pilot's Association for the Bay and River Delaware.**

# Maryland DGPS User's Guide for ver. 3.0

## Basic Setup of the DGPS Laptop Unit

1. Clamp the antenna on the bridge wing or flying bridge where it has a clear view of the sky.
2. Attach the cable to the antenna and protect it from being pinched in the door sill or the edge of the GPS case.
3. Plug the power cord into the ship's 110 or 220 volts AC power supply. Use an adapter plug for a 220 volt socket. **Please do not leave the adapter on the ship**. An extension power cord is included with the unit if needed.
4. The laptop battery has been replaced with a blank battery cartridge. This prevents the heat build up problem we were having. The more components you leave in the case the easier it is to put away and the less wear there will be on the wires and the foam. The Starlink DNAV 212 DGPS receiver should be left in its secure position in the molded foam.
5. Open the laptop. (Note that the laptop is being supplied AC power by the lighted "plug" symbol located above the keyboard.)
6. TURN ON the laptop computer by pressing the power button on the left side of the laptop. (Note the lighted "computer" symbol next to the AC power plug symbol.) When it is time to SHUT DOWN the computer - Press the same power button again but hold it in for 2 seconds. You will hear a beep. (Note the lighted computer symbol goes out.)
7. After the computer is turned on it will boot up and show you the Custom Menu screen for the Association of Maryland Pilots *(see insert 1)*. Press "p" on the keyboard to go to the Maryland Pilot Navigation Program.

## The Maryland Pilot Navigation Program

1. After pressing "p" to activate Starlink's custom program for the Maryland Pilots, you are prompted to enter the antenna offset from the vessel's centerline. It is important to enter this offset accurately as this affects the accuracy of the ship's position. You must enter an offset. If it is on the centerline enter zero.

2. The next screen you see is the **"Safety Reminder and Disclaimer Screen."** *(see insert 2)*

PLEASE READ IT CAREFULLY.

It is important that you remember that DGPS and ECDIS are only aids to piloting. Double check your position by other means and as always -

**<u>Keep a Good Lookout.</u>**

3. Assuming you pressed "y" the next screen you see is the

**[F-3] Menu Screen - "Association of Maryland Pilots Menu for <u>Control Functions and Routes</u>"**.*(see insert 3)* This screen is pretty straight forward but it will take you a little time to memorize all the control function keys. Remember, at any time you can press the [F-3] key to return to this screen. Feel free to change to a different display screen ([F-1],[F-2] or [F-3]). It will <u>not</u> affect the program or vessel's position.

## An Explanation of Each Control Function:

**[F-1] - Chart** : A display screen that shows a chart of the area with a track line, channel and buoys *(see insert 4)*. To the right side of the chart the following information is listed:

**WARNING OR MODE FLAGS** : These have been added to alert or inform the user of a problem or status of the program. They are also used to provide diagnostic information. A list and explanation of the flags follow:

**NOINIT** - The serial port is not configured properly. This prevents the program from <u>init</u>ializing properly.

**NOCOM** - No communication - The connection between the GPS unit and the serial port is broken or the A\C power has been lost to the laptop.

**NOPOS** - The DNAV 212 (the Starlink DGPS UNIT) is <u>no</u>t returning a <u>pos</u>ition solution. - (Possible break between antenna and receiver or insufficient number of satellites to obtain a position.)

**NODGPS** - <u>NO</u> <u>D</u>ifferential <u>GPS</u> - GPS only

**DGPS** - Receiving DGPS

**NO NAV** - The Ashtech GPS card in the DNAV is returning a solution mode that is not recognized.

**DOPLIM** - This flag is displayed when either HDOP or GDOP exceed specified limits. These limits are presently set at 3.0 for HDOP and 6.5 for GDOP. GDOP (geometric dilution of precision) is the product of the square roots of HDOP, VDOP and TDOP. DOP is a measurement of the quality of the fix due to the geometric positions of the satellites in respect to the position of the fix.

**LOGGING** - Recording all the information being received by the differential gps unit into a file named "data.log". This mode flag is not displayed on the [F-1] screen ; only on the [F-2] screen.

<u>The first time you press the "L" key to record a log of the vessel's transit it will erase any previous log (file name "data.log") and start a new file with the same file name.</u>

The following is a new feature of the logging program. To suspend logging press the "L" key a second time. To restart the logging feature and append it to the previous log press the "L" key a third time. Pressing the Q (Quit) key will ends the Starlink program and the log file.

**REPLAY LOG** - Playing back the information stored in the file "data.log". Pressing the "R" key now toggles the replay feature on and off. Another new improvement in the replay is now the time shown in the replay is the same as when the log was made. The logging and replay features are used mainly as a diagnostic tool for the technician to study any errors in the program's performance and as a classroom playback for instructional purposes. Remember the program can have only one file named "data.log". Therefore, each time you ran the Maryland program and you press the "L" key you will cause the program to write over the first log file and lose it forever. You can protect or save the data.log file in two ways. The first way is to move the file out of the directory C:\>MARYLAND where the program is located. The second way is to rename the file with the DOS command "Rename". example-
C:\MARYLAND\>RENAME DATA.LOG S120695.LOG
The new name can be up to eight letters plus a three letter extension. I used the route and the date to help identify the log. To replay this log you must rename the file back to "data.log" and have it in the Maryland directory. (END OF MODE AND WARNING FLAGS)

**OUT TO or IN TO and Waypoint #** : Route direction in or out of Baltimore and the waypoint # along the route.

**BRG** : The true <u>bearing</u> to the next waypoint.

**COG** : <u>Course Over the Ground.</u> The course the antenna is making good over the ground. Not the heading of the vessel.

**DIST** : The <u>Distance</u> to the next waypoint measured in nautical miles (nm) if the distance is greater than a mile. If the distance is a mile or less it is measured in feet (ft). When you get within about 200 feet of the waypoint the program automatically jumps to the next waypoint. You can advance to the next waypoint sooner by pressing the control function key "x" for ne<u>x</u>t.

**SOG** : <u>Speed Over the Ground</u> of the vessel (more accurate than the speed on the ship's GPS because of differential corrections).

**X** : The (R) right or (L) left <u>Cross Track Error</u> of the <u>antenna</u> measured in feet for the leg of the route the vessel is on. If the cross track error exceeds 9999 ft ( about 1.6 miles) the display posts a **WARN**ing flag. The program is designed to display only up to a four digit readout.

**TTG** : <u>Time To Go</u> to the next waypoint measured in hours and minutes.

**BCN** : Differential <u>Beacon</u> Frequency. There are three Coast Guard beacon stations in this area. The DGPS receiver is programmed to look only for them. The stations and frequencies are as follows:

| | |
|---|---|
| New York | 286 |
| Cape Henry | 289 |
| Cape Henlopen | 298 |

Below the Differential Beacon Frequency (BCN) there are three measurements to indicate the quality of the differential signal.

**SS** - Beacon Signal Strength - Should be no less than **20**
**SNR** - Signal Noise Ratio - Should be no less than **10**
**AGE** - Age ("Staleness") of Differential Data - **15** seconds or less - no greater than **30**

**ETA** : Estimated Time of Arrival to the end of the route based on the present speed. The arrival waypoint in Baltimore is up in the harbor at the intersection of the East channel and the Fort McHenry channel. Chesapeake City arrival point is about 6/10 miles east of Chesapeake City Bridge. Cape Henry arrival point is about 8/10 miles south of # 3 & 4 buoys.

**TIME** : The time of the internal clock in the laptop computer. Make sure that this time is correct. It affects your ETA at the end of the route. To correct the internal time clock of the computer you must go out of the navigation program. Press "q" to quit. Then press "d" to go to the DOS prompt. Type "time" and press [ENTER]. The computer responds *Enter new time:* enter military time or put an "a" or "p" after the time; for example: 20:15 or 8:15p. Press [ENTER] once the desired time has been typed. Then type "exit" and press [ENTER] to return to the custom menu screen.

**DATE** : DAY, DATE and MONTH

**FROM and TO Waypoint Numbers** - ex. 13C -> 14C

**[F-2] - Course Deviation** : This screen displays a large graphical presentation of the Cross Track Error of the GPS antenna (plus any manually input offset) as it goes along the route. *(see insert 5)* This graph is much easier to relate to than the number read out as displayed on the [F-1] screen. The graph shows the center line of the channel by a solid line in the middle and the quarters of the channel with dash lines. The half width of the channel is displayed in feet for all channels When the route is in the open Bay the graph is set to display 500 feet on each side of the centerline. When passing though a wide angle of a channel the graph only shows the standard channel width. This [F-2] screen displays all the information that is shown on the [F-1] Chart screen except the chart and the From and To waypoint numbers on the current range. Also, the "To" function does not display information on the [F-2] screen. The [F-2] screen shows in place of the chart the Cross Track Error graph discussed above and the following additional information :

1.) LAT. / LON. of the GPS antenna.
2.) The Mark LAT / LON position (discussed on the next page under M - Mark Position : )
3.) A list of all the satellites being tracked including their (PRN) number, (AZ) azimuth, (EL) elevation and (S/N) signal to noise ratio.
4.) On the left side of the F-2 screen under the Lat. / Lon. position there are three DOP values displayed:

**HDOP** = Horizontal Dilution of Precision
**VDOP** = Vertical Dilution of Precision
**TDOP** = Time Dilution of Precision

Their values are based on the position of the satellites with respect to your position (satellite geometry). The DOP values indicate the quality of your position fix. Their values should be as follows:

**HDOP** - The lower the better - Should be no greater than **3.0,** but not **0.**
**VDOP** - The lower the better - Should be no greater than **6.0,** but not **0.**
**TDOP** - The lower the better - Should be no greater than **6.0,** but not **0.**

(A zero value for one of these DOPs indicates that the current position is unreliable.)

**[F-3] - Menu** : The menu showing the Control Functions and the Routes

**U/D - Zoom Up / Down** : use to zoom in and out on the chart on the [F-1] screen.

**X/P - Next / Prior Wpt.** : used to advance to the next or backup to the previous waypoint along the selected route.

**R/L - Replay / Log** : REPLAY - Use to play back the information stored in the file "DATA.LOG". LOG - Recording all the information being received by the DNAV unit into a file named "DATA.LOG". For more information on this function see AN Explanation of Each Control Function page 4.

**+/- - Fast /Slow Read** : The [+] key makes it possible to replay the data.log file at a faster rate than the recorded speed. The [-] key slows down the replay of the data.log file.

**B - Display Brightness**: Press the "B" key to cycle between the day and night display. The NIGHT SCREEN feature has been added to reduce the Brightness of the display so your night vision will not be compromised. You can also use the **contrast control** keys (discussed on page 8) in conjunction with these day and night displays.

**C - Center Chart** : Pressing the "C' key will reset the postion of the antenna icon on the [F-1] Chart screen to the "look ahead" off-Center postion.

**M - Mark Position** : Press the "M" key to record the present Lat. / Lon. position on the [F-2] display screen just below the Lat. / Lon. readout. You can press this key at any time while viewing any screen. The marked position is also written to a file named "mark.dat" along with the current date and time. This Mark feature is useful in reporting a buoy adrift or man over board etc.

**Alt + M - Clear Mark** : This combination of keys clears the readout on the [F-2] screen.

**T - To Rng / Brg On /Off** : At any time, if you press the "T" key the mouse arrow and a readout of the ship's lat. / lon. will appear at the bottom of the screen. You can then move the mouse arrow to a desired position by pressing the small green mouse control button in the center of the keyboard. Place the arrow on a point in the screen that you want to measure the bearing and distance To. Then press the larger curved mouse button. This places a circle with a cross at the location and displays its lat. / lon. and the range / bearing to that position from the GPS antenna at the bottom of the screen. You may use the U/D keys to zoom the chart display up /down. To deactivate the "To" function repress "T" or press the small curved mouse button.

**Q - Quit Program** : Press the "Q" key to quit and leave the program.

# Route Menu:

Presently there are four routes to choose from in the Maryland program :

**S - Southbound Bay**
**N - Northbound Bay**
**E - Eastbound Canal**
**W - Westbound Canal**

Press the appropriate key to select your desired route. The GPS has to acquire a minimum of four (4) satellites in order to determine its position. This initial acquisition will take a minute or two. On the F-2 screen you can see the GPS acquire the satellites and determine its position. When you select your route, the program will automatically pick the next waypoint in front of you. ***However, if you select your route before the GPS has had a chance to determine its position it can not pick the correct waypoint.*** Once the GPS determines its position you can re-select your route (N, S, E, or W) and the proper waypoint will be picked. You can see the next waypoint that the GPS is using by the small circle on the [F-1] Chart screen. You can also see the distance and bearing to the wpt. on both the [F-1] and [F-2] screens. You should continually check to be sure that the program is using the proper waypoint.

## IMPORTANT INFORMATION on understanding and using the Starlink navigation program and the Toshiba 3400 CT laptop

1. **The Lat./ Lon. position and the Cross Track Error** are based on the location of the **antenna** plus any manually entered antenna offset from the centerline of the vessel. It is important to enter any offset accurately.
2. **The Icon** (in the shape of a ship) on the [F-1] screen shows the location of the antenna plus the antenna offset you enter. **The icon does not change size as you zoom up or down.** Therefore, it can be very misleading at different zoom levels. The icon can be much smaller than the actual vessel size.
3. **Contrast Control of the Laptop Screen**

   The contrast of the screen colors can be changed by holding down the [Right Shift] key and pressing the [Up] or [Down] Arrow key. Sometimes it take a few seconds of holding down these keys in order to see a change in contrast. The contrast program that controls the display screen is called "Colap". It works on M. S. DOS software but, does not function under Microsoft Windows. The program is automatically installed when the computer is turned on. The keyboard controls for the program are as follows:

[Right Shift] + [Up] / [Dn] Arrow key = adjust contrast
" + [Left Arrow] key = Restores colors to original settings
" + [Right Arrow] key = Blanks screen / press again to restore
" + [End] key = turns COLAP Prog. OFF --- DO NOT PRESS

If you accidentally press the [Right Shift] + [End] you will have to reboot the computer to reinstall COLAP.

Tilting the laptop screen away or toward you can greatly improve the display for different viewing heights and distances.

This version of the Starlink program will run in Microsoft Windows.

4. The Starlink navigation program has a feature in it to protect all file information. If any file is modified without authorization the navigation program will not run. Please do not try to go into any program files and modify them.
5. The [Fn]Function key (also referred to as the Hotkey) has been disabled in the setup program to prevent a multitude of possible problems. The laptop has several features that can interfere with the Starlink navigation program. These include screen savers installed by Toshiba that blank the screen after 3 or 30 minutes of non-keyboard use, a lock feature that instantly blanks the screen and disables the keyboard, and a feature that turns part of the keyboard into a numbers pad.
6. It is important that you are careful not to press the wrong key. If you meant to press "d" to zoom down but, you pressed "x" you will advance the waypoint. Simply stated : ***Any time a Control Function key is pressed that function will be executed.*** **Please Be Careful!**
7. The Starlink antenna is a combined GPS and Beacon crossed loop antenna. The number one problem with beacon antennas is finding a good ground connection. This antenna is self balanced and requires no ground connection.
8. The DGPS Beacon receiver is a two channel receiver to provide automatic beacon selection. Channel 1 continuously tracks the best available signal while channel 2 continuously scans the beacon frequency range locating, measuring and recording each beacon found. When a better beacon signal becomes available the receiver automatically switches channel 1 to the new frequency.
9. The antenna cable is not a braided wire. It is a solid copper wire which can break if kinked badly. Please protect it from damage. These units are expensive. Please take care of them as if they were your own. They can not be replaced easily.
10. The laptop computer now uses only AC power. The battery has been replaced with a blank cartridge. This will prevent charging heat build up. reduce the weight by 16 oz. and the navigation program will no longer continue to run without power to the DGPS receiver. The small charging light in the front left side of the laptop no longer is lit due to the battery being removed.
11. **Please return the DGPS unit in the condition in which you would like to find it.**
12. If you have any problems with the unit please make a note of it in the sign out book and let a Board member or me know about it.

DAF 8/94

**Custom menu for:**

**Association of Maryland Pilots**

**P Custom Pilot Navigation Program (maryland.exe)**

**G DNAV2 12 General Navigation Program (dnav2 1 2.exe)**

**D Go to DOS command prompt**

**W Start windows**

**Press either the P, G, D, or W key to select an option.**

**[P, G, D, W]?**

# INSERT # 1

# Safety Reminder

This system may be used only by individuals who are legally authorized to assume responsible charge for the safe operation of vessels. GPS is only an aid to piloting and navigation. It may provide incorrect information at any time, even if: you are following recommended operating procedures. Remember to look out the bridge window and verify that the GPS is correct.

Users of DGPS/ECDIS equipment are particularly cautioned to keep a good lookout The usual high performance of these systems may give you a false sense of security in problem situations. Also, the chart displays must be checked to ensure that features are accurately positioned. The Association of Maryland Pilots and the suppliers of this equipment do not assume any responsibility for public safety or the safe operation of any vessel.

If you accept these conditions and assume responsibility for the safe operation of this vessel, press 'y' to continue.

Otherwise, Press 'q' to quit.

INSERT#2

# Association of Maryland Pilots

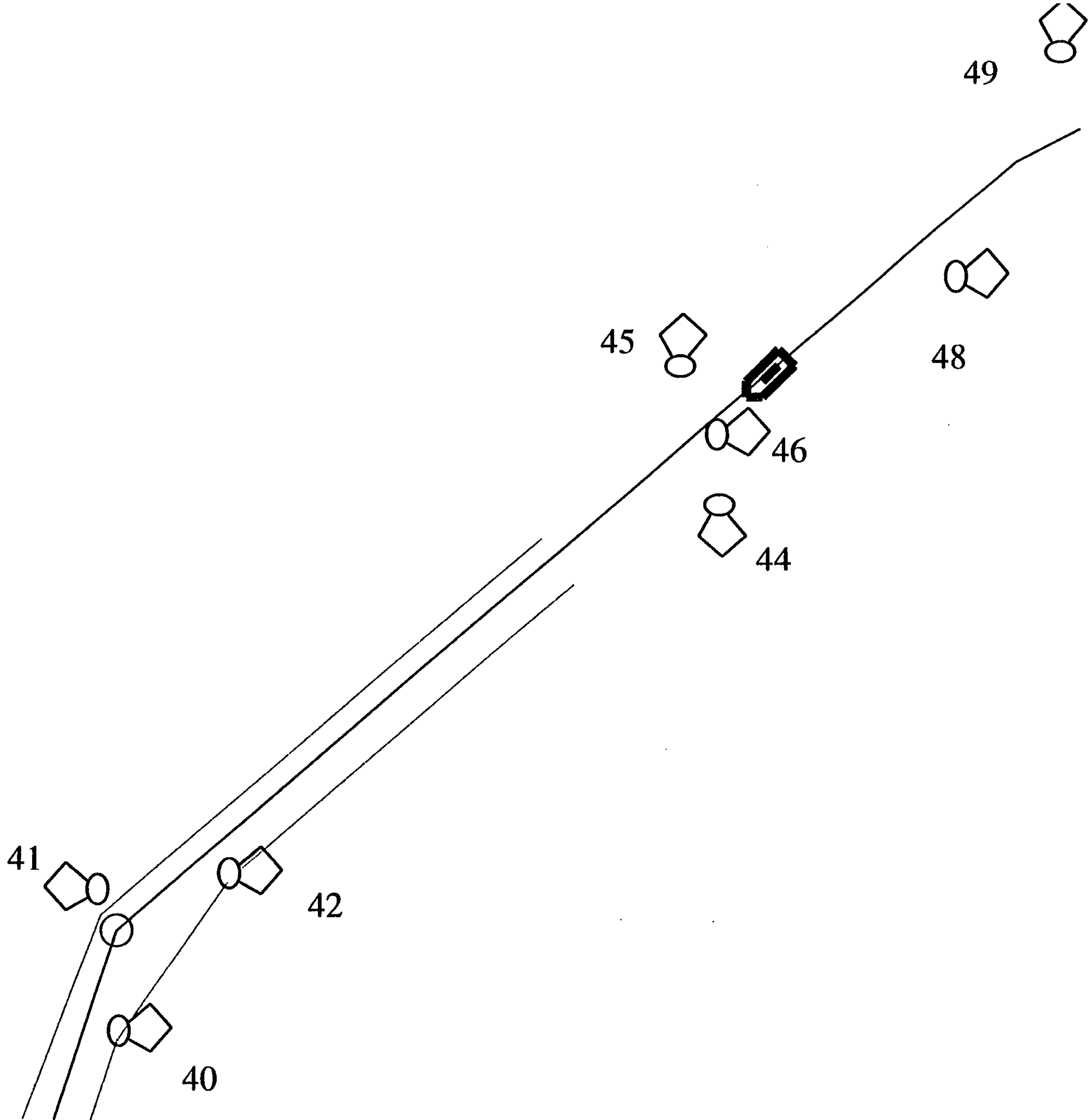
## Control Functions

Fl - Chart
F2 - Course Deviation
F3-Menu
U/D - Zoom Up / Down
X/P - Next / Prior wpt.
R/L - Replay / Log
+/- - Fast / Slow Replay
B - Display Brightness
C - Center Chart
M - Mark Position
Alt+M - Clear Mark
T- To Rng / Brg On / Off
Q - Quit Program

## Route Menu

S - Southbound Bay
N - Northbound Bay
E - Eastbound Canal
W - Westbound Canal

**INSERT #3**




| DGPS | |
|---|---|
| IN TO | 13C |
| BRG | 228 |
| COG | 227 |
| DIST | 739 NM |
| SOG | 14.7 KT |
| X | 67 FT |
| TTG | 00:07 |
| BCN | 289.0 |
| SS | 49 |
| SNR | 18 |
| AGE | 4 |
| ETA | 11:35 |
| TIME | 09:43 |

SUN 25 JUN

13C -> 14C

INSERT # 4

# DGPS

BRG TO WPT 228 COG 228

LAT N 39 19’7.342”

LON W 76 12’17.238”

MARK

LAT N 39 19’ 41.778”

MARK

LON W 76 11’ 57.078”

HDOP: 1.30 VDOP: 1.80 TDOP: 1.30

DIST 5000 FT

SOG 14.9 KT

IN TO 13C

TTG 00:03

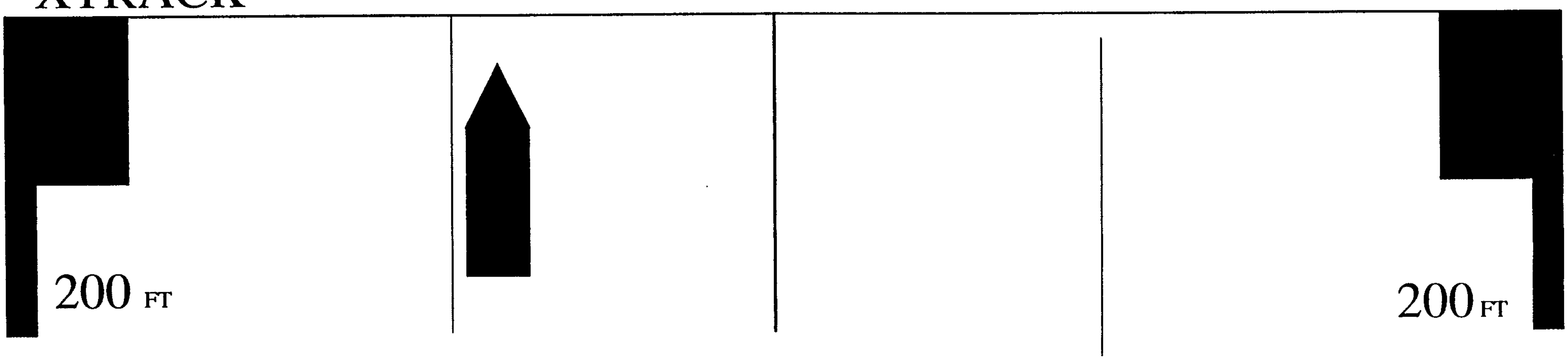
ETA 11:34

| BCN | SS | SNR | AGE |
|---|---|---|---|
| 298.0 | 48 | 19 | 6 |

| PRN | AZ | EL | S/N |
|---|---|---|---|
| 25 | 232 | 38 | 35 |
| 1 | 358 | 69 | 46 |
| 23 | 142 | 31 | 45 |
| 5 | 63 | 30 | 27 |
| 9 | 49 | 9 | 27 |
| 20 | 115 | 42 | 54 |
| 21 | 162 | 69 | 54 |

TIME 09:47
SUN 25 JUN

XTRACK




INSERT # 5